A STUDY OF THE EARLY LIFE HISTORY OF THE STRIPED BASS, *MORONE SAXATILIS*, IN THE COOS RIVER ESTUARY, OREGON.

by

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A THESIS

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APPROVED: ______________________

Paul P. Rudy

An Abstract of the Thesis of

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Title: A STUDY OF THE EARLY LIFE HISTORY OF THE STRIPED BASS, MORONE SAXATILIS, IN THE COOS RIVER ESTUARY, OREGON.

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The population of striped bass, Morone saxatilis, in Oregon's Coos River, has experienced a marked decline in numbers over the past two decades. This decline may be the result of low striped bass recruitment in the system. Successful recruitment is determined within the first two months of life. My research was aimed at the analysis of the causes of mortality at successive stages in the early life history of striped bass. The study, conducted on the spawning grounds of the South Fork Coos River in 1983 and 1984, monitored hydrographic conditions, zooplankton populations, abundance and distribution of eggs, larvae, and juveniles. Striped bass recruitment was poor during both years; egg densities were variable and larval densities were extremely low. High flow conditions hampered sucessful egg incubation both years, and low zooplankton populations limited larval success. The relationship between successful recruitment and river flow in the Coos River is discussed.

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CHAPTER I

INTRODUCTION

The striped bass (Morone saxatilis) is an anadromous fish native to Atlantic coast waters. It is a widely acclaimed sport fish and, in some areas, an important commercial fish. It was introduced to the Pacific coast in 1879 when 132 yearling striped bass from the Navesink River, New Jersey were taken across the continent by train and introduced into the lower Sacramento River, California. Three years later 300 additional yearlings were introduced in the same waters (Morgan and Gerlach, 1950). From this meager start, the striped bass has become very successful on the west coast, spreading along the coast from as far south as Ensenada, Mexico northwards to British Columbia, Canada (Forrester, et al., 1972).

The first reported striped bass taken in Oregon waters were caught in Coos Bay by gill netters in 1914 (Morgan and Gerlach, 1950). In subsequent years the population became well established and by the late 1920's a substantial commercial and sport fishery had evolved (Bender, 1980). Partial landings for 1928 were 8,200 pounds, and for 1930, 13,400 pounds. Annual statistics for the entire Oregon catch are available since 1931 when 18,000 pounds were caught. The largest catch was made in 1945 when 263,000 pounds were landed (Morgan and Gerlach, 1950).

Bender (1980), using commercial harvest rate data, estimated that the 1945 population of age 3 or older striped bass was in excess of 75,000. Harvest rates varied widely in subsequent years but started a steady decline in 1966 and amounted to only 4,026 pounds in Coos Bay in 1975 when the commercial fishery was eliminated by legislative action (McGie and Mullen, 1979). Without a commercial fishery it is impossible to statistically estimate present population levels, but by general consensus the adult population in Coos Bay is low with the most recent estimates putting the numbers of adult aged 3 and older at less than 10,000 (Bender, Personal Communication).

Decreasing numbers of striped bass are not a problem isolated to Coos Bay. Elsewhere on the Pacific coast estimates of the striped bass population are scant and highly variable, but there is a general agreement that estuarine populations are declining in abundance. The decline of striped bass within Chesapeake Bay and other east coast populations is even more dramatic than on the west coast. Estimates of the commercial harvest from Maryland waters of Chesapeake Bay in 1983 was around 300,000 pounds representing a 94% decline over the past ten years from the 4,725,000 pounds which were commercially harvested from these same waters in 1973. The Maryland Department of Natural Resources indicated that striped bass year-class strength over the past ten years (1974-1983) has averaged less than half the average over the previous twenty years (1954-1973) (SFI Bulletin, 1984). The problem has become so acute that Maryland has declared a moratorium on the commercial and sport fishery for striped bass effective January 1, 1985 in an attempt to halt the decline in broodstock numbers until the factors underlying their poor recruitment can be accurately assessed and rectified (SFI Bulletin, 1984). Increasing concern over the steady decline of the fishery in California throughout the past decade has prompted the California State Water Resource Control Board to seek the principle factors contributing to this decline (Action Plan, 1981).

The decline in numbers of striped bass may be the result of overfishing, habitat deterioration, the effect of industrial development, and/or an extended sequence of natural events that have not favored the production of dominant year classes (Action Plan, 1980). Investigators of the Hudson, Potomac and Sacramento-San Joaquin Rivers recognized that year-class strength is determined within the first two months of life and positive correlations have been established between young-of-the-year abundance and the ensuing year-class strength (Westin and Rogers, 1978).

McGie and Mullen (1979) hypothesized that year-class dominance in Oregon is most likely related to low parent stock densities followed by one or more favorable environmental factors enhancing survival of eggs or juveniles. If this is true then striped bass recruitment at low parent densities is determined by density-independent factors. These factors include water-flow rates, both velocity and volume (Turner and Chadwick, 1972), water temperature and salinity (Morgan, et al., 1981), suspended solids present (Auld and Schubel, 1978), dissolved oxygen levels, water pH, predation, prey availability, genetic defects, disease, and contaminant toxicity (Action Plan, 1980).

There is, however, very little data available on Oregon's populations to substantiate this hypothesis. The only published life history notes on Oregon striped bass are those of Morgan and Gerlach (1950) for the Coos River population, and details on the early life history are limited in this report. Research is needed to gather baseline data in early life stages of striped bass in Oregon as well as to document the correlations between environmental parameters and striped bass year-class strength (Gould, 1980). The role of food availability as a critical factor in determining year class success needs further investigation. The extrinsic events, such as temperature and riverflow, which may influence that food availability, are poorly understood and also merit further study (Setzler-Hamilton, et al, 1980). More complete studies of temperature selection by small striped bass in the field are also needed (Cox and Coutant, 1981). This information would help us understand the causes of low recruitment and subsequent population declines that are evident in Coos Bay.

My research, therefore, was aimed at the analysis of the extent and causes of mortality at succesive stages in the early life cycle of the striped bass in the Coos Bay Estuary. The specific objectives of my study were to: (1) measure the chemical, physical, and biological environment of the river/estuary; (2) determine the abundance of zooplankton prey species in areas where striped bass fry occur; (3) document the distribution and abundance of striped bass eggs, larvae, and fry; and (4) integrate the above data in an attempt to determine the major factors underlying the low recruitment in the Coos Bay estuary.

CHAPTER II

METHODS AND MATERIALS

The Study Area

Coos Bay is located some 325 kilometers south of the Columbia River mouth and is the second largest estuary in Oregon (Percy, *et al.*, 1974). It covers an estimated 2,470 hectares and is fed chiefly by the Coos River from the east (US Army Corp, 1976). The Coos River is formed by the confluence of the Millicoma River from the northeast and the South Fork Coos River from the southeast at river kilometer 8.9.

Although there are no gauging stations operating in the Coos river drainage basin, estimates of the average monthly discharge of the Coos, South Fork Coos and Millicoma Rivers have been made and are shown in Table 1 (Percy, *et al.*, 1974). These flow rates vary considerably, depending mainly upon seasonal fluctuations in precipitation.

The Army Corps of Engineers maintain a navigation channel 1.5 m deep and 15.2 m wide in the Coos River and its two tributaries, which is reduced to a 0.9 m depth in the upper navigable reaches of the South Fork Coos River (US Army Corp, 1976).

Tidewater extends upstream about 18 river km beyond the fork in each tributary and the estuary is defined as well-mixed during periods

Table 1. Flow rates of Coos Bay tributaries (From Percy, *et al.*, 1974).

Stream (at mouth)	Drainage Area (hectares)	Average Monthly Flow (m^3/s) High	Low	Mean
Coos River	107,530	155.7 February	2.55 August September	62.28
S. Fork Coos River	65,813	93.43 February	1.42 August September	36.80
Millicoma River	39,126	62.29 February	0.85 September	24.63

of low run-off to a partially mixed estuary during periods of maximum run-off (Percy, et al., 1974).

The water quality in Coos Bay is highly variable and depends on specific location in the bay and season. Domestic sewage, log rafting and increased stream sedimentation, leachates and organic material carried into the river resulting from logging activities exert increased biochemical oxygen demand (BOD), thereby creating oxygen deficiencies in parts of the estuary. At various sampling locations within the bay, dissolved oxygen levels are low and the temperature, coliform, and turbidity levels are high (US Army Corp, 1976).

Striped bass spawn in both tributaries of the Coos River. My sampling was conducted in the primary spawning grounds located in the Coos and South Fork Coos rivers.

Data Collection

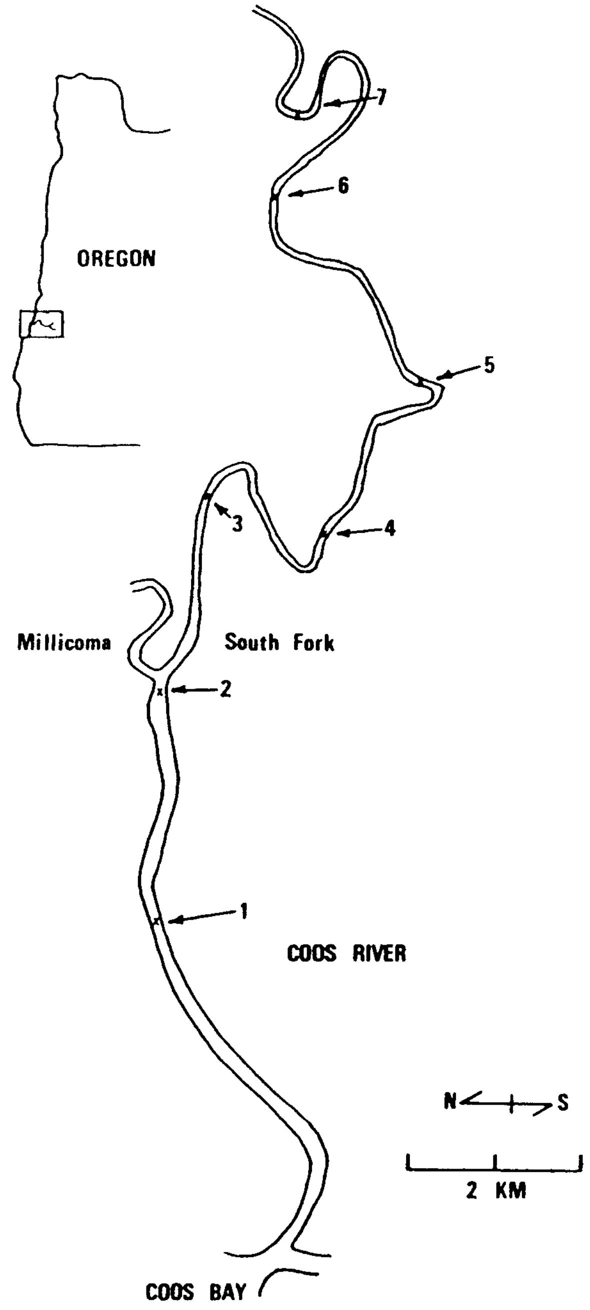
Sampling began on April 13, 1983, and was conducted once a week through May, twice a week in June, once a week in July, twice in August and once in September. Sampling in 1984 was more condensed beginning on May 13 and concluding June 28. Sampling intervals varied with spawning activity, ranging from 2 to 9 days throughout the study period (Table 2).

The study area was subdivided into seven sampling sites beginning at river km 6.4, approximately 2.4 km west of the confluence of the Millicoma and South Fork Coos Rivers and progressing up the South Fork with subsequent sites spaced at 2.4 km intervals (Figure 1). In 1983, three stations per transect were sampled at transects one through

Table 2. Dates and locations of ichthyoplankton and zooplankton sampling, South Fork Coos River, 1983-1984.

1983			1984		
Cruise #	Date	Sites Sampled	Cruise #	Date	Sites Sampled
1	4/13	2-7	1	5/13	2-5
2	4/20	2-7	2	5/20	2-5
3	4/27	2-6	3	5/27	2-5
4	5/4	2-7	4	5/30	2-6
5	5/11	2-7	5	6/1	2-7
6	5/18	5,7	6	6/3	1-6
7	5/22	2,4,6	7	6/5	1-6
8	5/26	3-7	8	6/9	2-6
9	6/1	2-7	9	6/16	1-6
10	6/5	2-6	10	6/19	1-6
11	6/8	2-7	11	6/28	1-5
12	6/12	2-6			
13	6/15	2-7			
14	6/19	1-6			
15	6/23	1-7			
16	6/26	1-7			
17	6/29	1-7			
18	7/3	1-7			
19	7/11	1-5			
20	7/17	1-7			
21	7/24	1-7			
22	8/8	1-7			
23	8/21	2-7			
24	9/25	2-7			

Figure 1. Location of the study site on the Coos River, Oregon. Transect locations are marked with an "x".



OREGON
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Millicoma
South Fork
COOS RIVER
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S
2 KM
COOS BAY

five; a surface station, bottom station, and shoal station. The surface station only was sampled at transects six and seven due to shallow conditions there. In 1984 the shoal station was eliminated as well as transect seven leaving two stations each for transects one through five and one station for transect six.

A 5 meter, flat-bottomed aluminum boat, powered by a 20 HP Mercury outboard, was used to conduct the sampling. Sampling methodologies and procedures closely paralleled those used by Setzler-Hamilton, et al. (1977).

Hydrographic Parameters

Water temperature, salinity, turbidity, and depth were measured at each station in 1983. These same parameters, plus a single pH measurement taken at transect three, were measured in 1984. A continuous water temperature profile was obtained from a recording thermogragh placed in the study area by the Oregon Department of Fish and Wildlife. Salinity was measured with a YSI Model 33 salinity meter. Turbidity measurements were made with a Secchi disc, and depth measurements were made with a weighted, calibrated line. Measurements of pH were made with a Corning, Model 12, research pH meter. Weather conditions and tidal cycle at the time of sampling were also noted. Daily precipitation totals were obtained from the Federal Aviation Administration recording station at the North Bend airport. Flow rates and non-tidal-drift rates in 1983 and 1984 for the South Fork Coos River were estimated using river gauging data recorded in the Coquille River basin on the South Fork Coquille River at Powers, Oregon. Average daily flow rates in ft^3/sec for this station were obtained from the Water Resources Department in Salem, Oregon. These values were converted to m^3/sec and an estimate of South Fork Coos river flow was obtained by dividing the drainage area of the South Fork Coos river (254 $mi.^2$) by the drainage area of the South Fork Coquille River above Powers (169 sq. mi.) and subsequently using this factor (1.503) to convert riverflows on the Coquille into riverflows on the South Fork Coos. Although this method does not account for differences in precipitation rates between the two drainage basins, I was assured by Ben Scales, a hydrographer with the Water Resources Department, that this is an accepted method for extrapolating flow rates in an ungauged drainage basin from known flow rates in a gauged drainage basin, especially if the two watersheds are adjacent and have similar drainage patterns as is the case for the Coos and Coquille systems. Non-tidal-drift rates (the net distances per day which the water must move seaward in order to carry the water from the river out of the estuary) were calculated using the following formula from Perkins (1976):

$$\text{N.T.D.} = \frac{\text{River Flow}}{\text{F (River Cross Sectional Area)}}$$

where F is the average proportion of river water in a sample,

$$F = \frac{S-So}{S},$$

S is the salinity of the open ocean and So the salinity of the estuarine sample. The average daily flow rate (in m^3/sec) was converted to a total daily river flow by multiplying it by 86,400 sec/day. This result was divided by the average cross sectional area of the study area (80 m^2) and this result was divided by 1,000 m/km to obtain, in kilometers, the daily non-tidal drift. Since no salinities were recorded above the Coos river fork during the periods of time that the flow rates were calculated, I assumed that F=1 at all times.

Phytoplankton Studies

A quantitative measurement of phytoplankton was made in 1983 using the fluorometric method for *in vivo* chlorophyll *a* measurement (Flemer, 1969). Profiles of fluorescence and corresponding chlorophyll *a* concentrations were made for the entire study site by pumping water continuously through a fluorometer while towing a submersible pump from one end of the study area to the other.

A Turner Model 19 fluorometer, equipped with a continuous readout, linear chart recorder, was used for the field measurements. To standardize this measurement several "grab samples" of water were taken during the sampling and spectrophotometrically analyzed to determine the amount of chlorophyll pigments present. This was done by first filtering the phytoplankters from the grab sample onto a Whatman 4.5 cm GF/C glass millipore filter. The chlorophyll pigments were extracted from the algae cells by grinding the filter and filtrate, with a mortar and pestle, in 50 ml of laboratory grade acetone and allowing the homogenate to stand in a refrigerator overnight. This solution was then centrifuged and the supernatent placed into a 10 cm cylindrical cuvette. The absorbance (E) of this solution was then measured against a cell containing 90% acetone at wavelengths 750, 665, 645 and 630 nm using a Bausch & Lomb Spectronic

70 spectrophotometer. Values for chlorophyll a concentrations were then calculated using the Strickland and Parsons equations (1968):

$$C_a = 11.6\ (E_{6650} - 2.0\ (E_{6450}) - 0.8\ (E_{6300})\quad \text{and,}$$

$$\text{mg chlorophyll } \underline{a} \ / \ m^3 \text{ water} = C_a \ / \ V$$

where V = Volume of grab sample filtered

Chlorophyll a concentrations at all sites were then derived using the values calculated for the grab samples and the continous linear fluorometric recording that was taken in the field.

Zooplankton Studies

Zooplankton samples were collected by filtering 60-80 liters of water, pumped with a Rule, 800 gallon per hour, submersible bilge pump, through a #20 (76 micrometer mesh) plankton net at each station. The samples were concentrated to a final volume of about 100 ml, stained with Rose Bengal, and preserved in a 5% formalin solution.

Field collection samples were further concentrated to exactly 50 ml in the laboratory and two 1 ml aliquots were withdrawn from well-mixed samples with a Hensen-Stempel pipette. These samples were examined under an American Optical, 0.7X to 4.2X binocular zoom dissecting scope. Zooplankton were counted and identified to the lowest possible taxa and the results from the two aliquots were averaged and converted into numbers of organisms per m^3 of water (1,000 liters).

In 1983, 183 zooplankton samples were analyzed from the 78 transects sampled. A total of 12,900 liters of water were filtered for an average of 70.49 liters/sample. In 1984, 54 zooplankton samples were analyzed from the 29 transects that were sampled with an average of 60.00 liters of water filtered/sample.

Counts of adult copepods were made only to the order level because of the time and difficulty involved in accurately identifying the animals to a lower taxon; all copepodite and nauplii stages counted were added together, regardless of species, for the same reasons. Although the adults were identified only to order as they were counted, an attempt was made later to identify the most abundant species within the two orders that were enumerated. The harpacticoids were positively identified only to the family level.

Ichthyoplankton Studies

The distribution and abundance of eggs and larvae were monitored by ichthyoplankton tows. Sampling at each station was conducted using two 0.5 meter #0 (571 micrometer mesh) plankton nets harnessed together into a bongo net with a General Oceanics Model 2030-R calibrated flowmeter installed in one of the nets. Tows were made against the current and filtered approximately 50 m^3 of water (50,000 liters). The collected samples were washed into collecting jars and preserved in a 5% solution of formaldehyde containing Rose Bengal for staining.

Field collections were sorted in the laboratory using a white dissecting pan and small forceps. A pipette was used for sorting eggs. Eggs, larvae, and larger zooplankters were counted and sorted to the lowest possible taxa, and the results from the two nets were averaged and converted into numbers of organisms per 1,000 m^3 of water

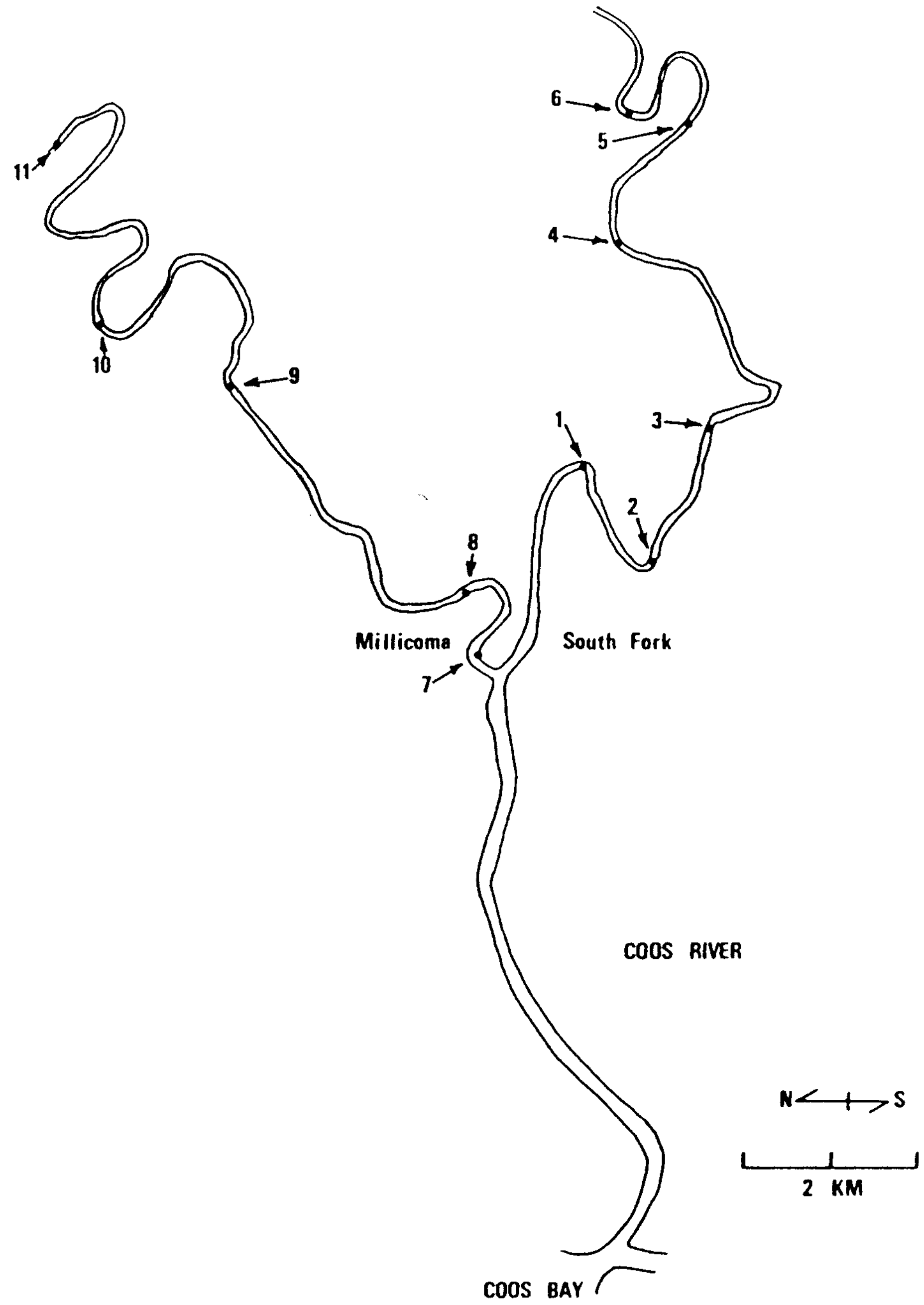
(10^6 liters).

In 1983, 387 plankton samples were analyzed from 201 bongo net tows taken at 87 transects. A total of approximately 14,819 m^3 of water were filtered for an average of 38.3 m^3 filtered per sample analyzed. In 1984, 208 samples were analyzed from 104 bongo net tows taken at 56 transects. A total of approximately 5,000 m^3 of water were filtered this year for an average of 24.0 m^3 per sample.

Juvenile Fish Studies

Juvenile striped bass collections were made by the Oregon Department of Fish and Wildlife in conjunction with summer seining surveys on the South Fork Coos and Millicoma rivers. Collections were made every two weeks from the first of July through September with a 38 meter beach seine at 6 river sites on the South Fork Coos River and at 5 sites on the Millicoma River (Figure 2). Site number three was sampled twice; once at low tide and again on the return trip in the middle of the incoming tide for a total of twelve sets per sampling date. Numbers and sizes of juveniles seined at each location were recorded.

Figure 2. Location of river seining sites on the South Fork Coos and Millicoma rivers.



11
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1
Millicoma
South Fork
COOS RIVER
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S
2 KM
COOS BAY

CHAPTER III

RESULTS

Data presented in this section will be confined to that which was collected during the pertinent time periods of striped bass spawning activity and the associated presence or absence of striped bass eggs or larvae in collections. More specifically, the data collected at least two weeks prior to any spawning activity until at least one week after the last signs of striped bass eggs or larvae were detected. In 1983, this period was from May 1 through July 11; in 1984, the period of activity was from May 13 through June 28.

Hydrographic Parameters

Temperature

The temperature, turbidity, and flow rate patterns throughout the study area are presented in Figure 3 and appear to be closely correlated with seasonal rainfall and riverflow (Table 3). The Pearson correlation between water temperature and flow rate was highly significant ($p<0.001$) for both years ($r^2 = 0.82$ in 1983 and $r^2 = 0.68$ in 1984). Flow rates affected river temperatures according to the regression:

$$\text{River Temperature} = 19.03 - 0.19\ (\text{Flow Rate})$$

where flow is the daily average in m^3 per second and temperature is

Figure 3. Water temperature, flow rate, and Secchi depth reading on the South Fork Coos River in 1983 and 1984.

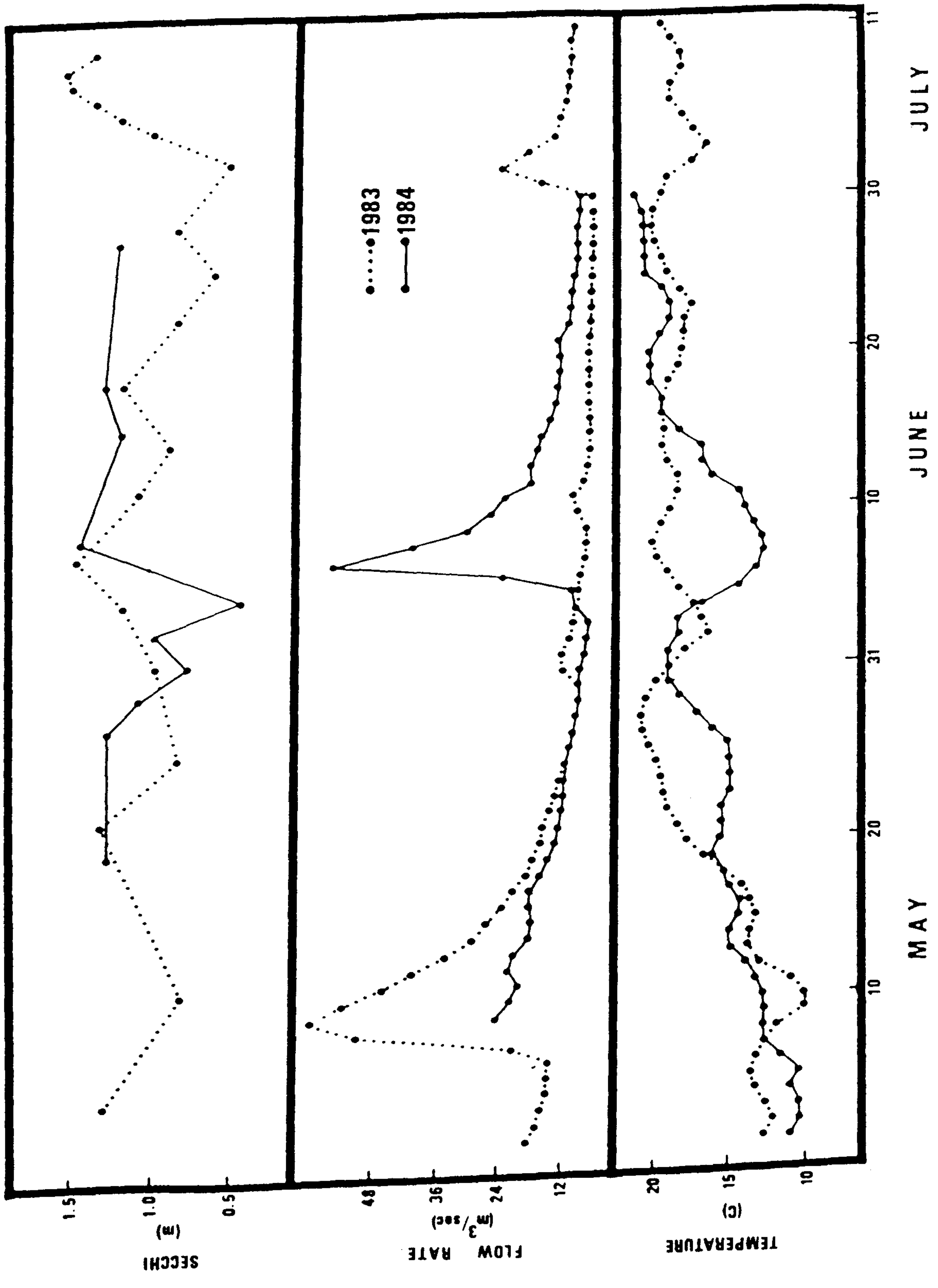

SECCHI (m)
1.5
1.0
0.5
FLOW RATE (m³/sec)
48
36
24
12
TEMPERATURE (C)
20
15
10
1983
1984
MAY
JUNE
JULY
10
20
31
10
20
30
11

Table 3. Daily precipitation, water temperature, flow rate and non-tidal-drift rate in the South Fork Coos River, 1983 and 1984.

	1983				1984			
Date	Precip (cm)	Temp (^{o}C)	Flow (m^3/s)	NTD (km)	Precip (cm)	Temp (^{o}C)	Flow (m^3/s)	NTD (km)
1	.01	12.5	17.02	18.38	3.61	10.6	-*	-
2	.08	11.9	15.54	16.79	1.65	10.0	-	-
3	.00	12.2	14.44	15.59	.18	10.0	-	-
4	.01	12.8	13.36	14.43	.56	10.6	-	-
5	.13	13.1	12.54	13.55	.38	10.0	-	-
6	.36	12.8	12.12	13.09	.00	11.1	-	-
7	2.29	12.2	20.05	21.65	.00	12.2	-	-
8	2.18	11.4	49.35	53.30	.61	12.2	23.28	25.14
9	1.45	9.7	57.87	62.50	.33	12.2	20.77	22.43
10	.01	9.7	51.93	56.08	1.17	12.2	18.34	19.81
11	.00	10.6	44.25	47.79	.53	12.8	20.04	21.65
12	.00	12.5	38.68	41.77	.00	13.4	18.51	19.99
13	.05	13.4	32.50	35.10	.15	14.4	15.91	17.19
14	.23	13.1	27.49	29.69	.43	14.4	15.62	16.87
MAY 15	.00	12.8	25.31	27.34	.48	13.9	16.60	17.92
16	.13	13.1	22.74	24.55	.00	13.9	15.62	16.87
17	.00	13.9	19.96	21.56	.00	14.4	14.08	15.21
18	.00	15.0	17.78	19.20	.00	15.0	12.81	13.83
19	.00	16.1	16.05	17.34	.74	15.6	11.79	12.73
20	.00	17.2	14.55	15.72	.01	15.0	11.32	12.22
21	.00	17.8	13.19	14.25	.00	15.0	10.34	11.17
22	.00	18.6	12.09	13.06	1.45	15.0	9.70	10.48
23	.00	18.9	11.10	11.99	.03	14.4	10.47	11.31
24	.00	19.0	10.22	11.04	.08	14.4	9.36	10.11
25	.01	19.2	9.40	10.15	.43	14.4	8.55	9.24
26	.00	19.7	8.78	9.48	.20	14.4	8.98	9.70
27	.00	20.0	8.13	8.78	.00	15.6	8.55	9.24
28	.00	20.1	7.53	8.13	.00	16.7	7.74	8.36
29	.01	19.7	6.99	7.55	.10	17.8	7.11	7.67
30	.05	19.2	6.65	7.19	.00	18.3	6.72	7.26
31	.03	18.3	9.82	10.61	.00	18.3	6.38	6.89

* Flow Data Unavailable For These Dates.

Table 3 continued.

	1983				1984			
Date	Precip (cm)	Temp (°C)	Flow (m^3/s)	NTD (km)	Precip (cm)	Temp (°C)	Flow (m^3/s)	NTD (km)
1	.05	17.2	10.42	11.25	.00	18.3	5.91	6.39
2	.05	15.8	8.78	9.48	.00	17.8	5.62	6.07
3	.00	16.1	8.01	8.65	.79	17.8	5.45	5.88
4	.00	16.7	7.16	7.74	2.54	16.1	6.34	6.85
5	.00	17.8	6.51	7.03	.99	13.9	8.72	9.42
6	.00	18.6	6.00	6.48	2.62	12.8	21.32	23.02
7	.03	19.2	5.69	6.15	.20	12.2	53.62	57.91
8	.08	19.4	5.32	5.75	.00	12.2	38.89	42.00
9	.23	18.9	5.01	5.41	.89	12.8	28.47	30.75
10	2.03	18.3	6.17	6.67	.00	13.4	23.62	25.51
11	.13	17.9	6.99	7.55	.00	13.9	20.21	21.83
12	.00	17.8	5.75	6.21	.00	15.6	15.45	16.68
13	.00	18.6	5.07	5.47	.00	16.1	16.26	17.56
14	.91	18.9	4.73	5.11	.00	16.1	14.64	15.81
JUN 15	.08	18.6	4.93	5.32	.01	17.8	13.15	14.20
16	.00	18.9	4.64	5.01	.00	18.9	12.00	12.96
17	.30	18.9	4.30	4.65	.00	18.9	11.11	11.99
18	.41	18.3	4.67	5.05	.00	19.4	10.17	10.98
19	.66	17.8	4.84	5.23	.01	19.4	9.49	10.25
20	.00	17.2	4.50	4.86	.25	19.4	9.45	10.20
21	.00	17.2	4.16	4.49	.05	18.9	10.00	10.80
22	.48	17.2	3.91	4.22	.00	18.3	8.98	9.70
23	.18	16.9	3.96	4.28	.00	18.3	8.13	8.78
24	.00	17.5	3.96	4.28	.00	18.9	7.57	8.18
25	.00	18.6	3.65	3.94	.00	20.0	7.11	7.67
26	.00	18.9	3.45	3.73	.30	20.0	6.68	7.22
27	.01	19.2	3.31	3.58	.10	20.0	6.51	7.03
28	.01	19.4	3.20	3.46	1.35	20.0	6.34	6.85
29	.05	19.2	3.20	3.46	.10	20.0	6.17	6.66
30	.64	18.9	3.14	3.39	.00	20.6	5.87	6.34
1	3.28	18.3	14.35	15.50				
2	1.02	16.7	21.80	23.54				
3	.00	15.8	15.29	16.51				
4	.00	16.9	11.33	12.23				
JUL 5	.00	17.5	9.46	10.21				
6	.94	18.3	8.30	8.96				
7	.43	18.1	7.70	8.32				
8	.43	17.5	7.70	8.32				
9	.00	17.5	7.36	7.95				
10	.00	18.1	6.60	7.13				
11	.00	18.9	6.12	6.61				
Means	.27	16.7	12.48	13.48	.38	15.5	13.18	14.24

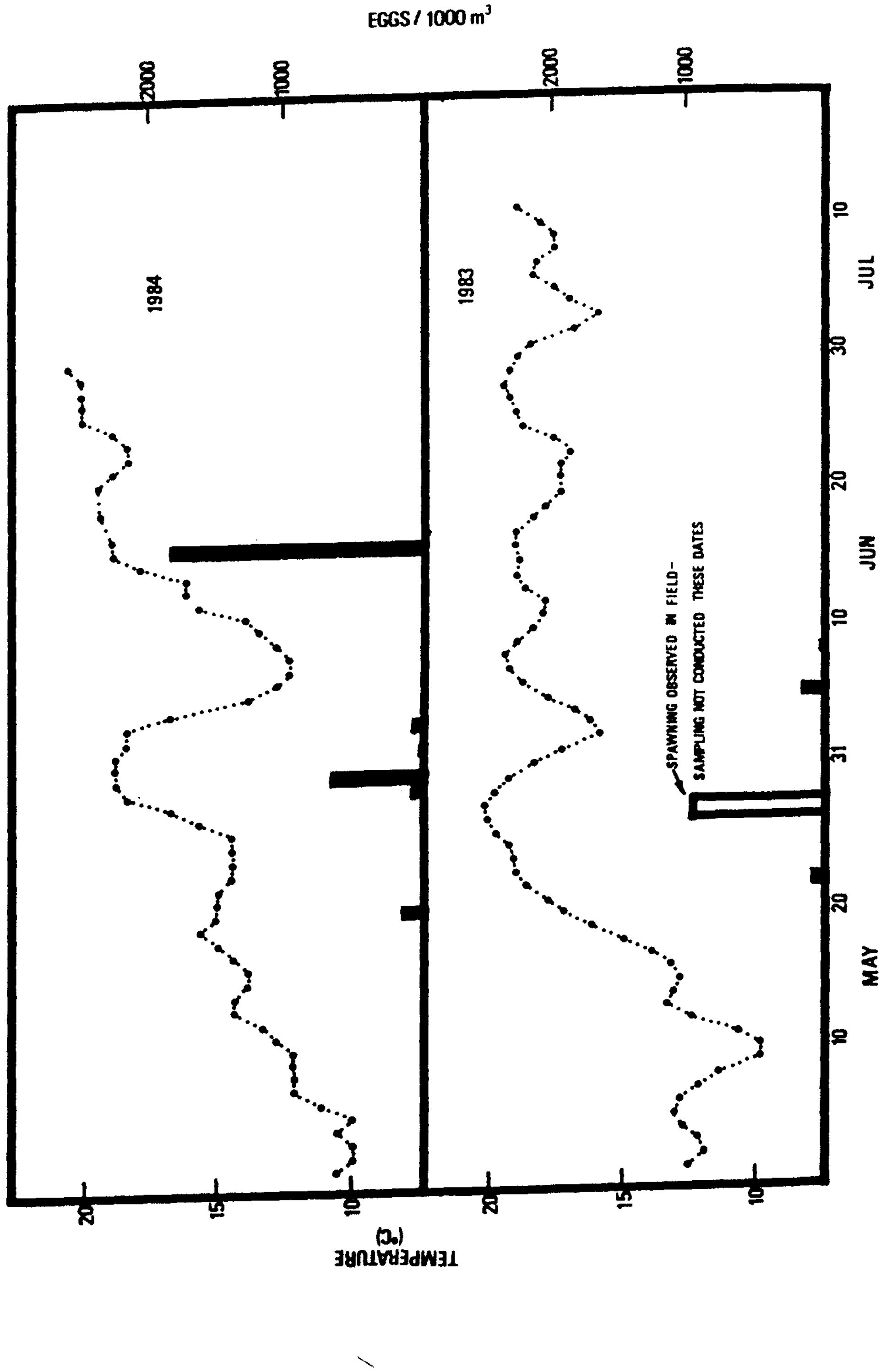
the daily average in degrees C.

Average daily water temperatures for the 1983 and 1984 sampling seasons were calculated from thermograph data recorded near transect four (Table 3). Temperatures ranged from 10.6 C to 24.4 C depending on the time of year, cloud cover and, most importantly, the amount of freshwater runoff entering the river. The river system was very susceptible to rapid temperature drops associated with overcast, cool weather conditions, and large freshets associated with the precipitation in the area. In 1983 the temperature dropped over 4.5 C in just 5 days during a very critical time of striped bass spawning, and temperatures fluctuated widely during the entire course of the season. A similar situation manifested itself during the 1984 season as temperatures climbed steadily prior to spawning activity and then dropped abruptly several days after the onset of spawning when a major freshet came through the area (Figure 4). Average water temperature in 1983 was 16.7 C, more than a full degree over 1984's average of 15.5 C.

Non-Tidal-Drift

Measurements of stream flow and estimates of non-tidal-drift rates through the study area were highly variable and most closely related to daily fluctuations in precipitation (Table 3). Daily precipitation ranged from 0 to 3.28 cm in 1983 and from 0 to 3.61 cm in 1984. Daily non-tidal-drift rates ranged from just over 3 km to over 60 km in 1983; 1984 values were similar ranging from a low of approximately 6 km upwards to 58 km. The mean non-tidal-drift rate in

Figure 4. Water temperature versus study area mean striped bass egg density on the South Fork Coos River in 1983 and 1984.


EGGS / 1000 m³
2000
1000
2000
1000
1984
1983
SPAWNING OBSERVED IN FIELD-
SAMPLING NOT CONDUCTED THESE DATES
10
JUL
30
20
JUN
10
31
20
MAY
10
TEMPERATURE
(°C)
20
15
10
20
15
10

1983 was 13.5 km/day; 1984's mean was slightly higher at 14.2 km/day.

Salinity

The salinity pattern within the study area (Appendix A) was highly variable but appeared to be related to riverflow, stage of tide, and time of year. The salt wedge tended to progress upriver during the study period as the riverflows diminished. Higher salinities were also recorded on incoming tides. The highest recorded salinity in 1983 was 24 ppt at site #1. Salt water penetrated upstream as far as site #4 in late July when salinities of 2 ppt were recorded. Surface salinities were usually 1 to 2 ppt lower than bottom salinities. Fresh water was predominant in the 1984 sampling season when no salinities were recorded until the last two sampling sessions in late June. Salinity was recorded only at sites 1 and 2 in 1984 and peaked at 18 ppt at site #1 at the end of June.

Turbidity

Secchi disk measurements varied from 0.25 m to 2.4 m. Average Secchi measurements for the study site are shown for each sampling date in Figure 3. Measurements appeared to be somewhat related to seasonal fluctuations in river flow but mainly attributable to the daily tugboat traffic through the area. The waterway is used extensively by the Weyerhaeuser Corporation for the transport of logs that are towed downstream in large rafts by powerful tugboats. On the average, two of these tugboats pass through the area every day. The propwash and wake from these boats keep particulate matter suspended in the water column. Turbidity was usually fairly consistent from site to site throughout the study area with the exception of measurements taken above the log dump beyond any tugboat activity, where turbidity dropped off abruptly. Weyerhaeuser suspended rafting operations for a period of one week in early July of 1983, and daily Secchi measurements taken during that period of time went from 0.5 m on July 3, the date when rafting was suspended, to 1.45 m on July 9, the date before rafting was resumed. Measurements dropped to 1.25 m on July 10 and were down to 0.9 m on July 11, after only two days of rafting activity.

pH

Seven weekly pH measurements were taken during the 1984 sampling season at transect three on cruises 1, 2, 3, 6, 8, 9 and 10. Measurements were 7.8, 7.7, 7.8, 7.8, 7.6, 7.8 and 7.8 for the respective cruises for an average pH for the season of 7.75.

Primary Production

A total of ten fluorometric, chlorophyll profiles of the study area were taken in 1983 to assess the primary productivity (Table 4). Measured values followed no obvious specific patterns within the study area and mean chlorophyll a concentration varied widely from cruise to cruise. No clear correlation between chlorophyll a concentrations to water temperature, riverflow, turbidity, or zooplankton densities were apparent. This lack of correlation with the other monitored parameters and the high variability of my results were most likely due

Table 4. Chlorophyll a Concentrations, by site;
South Fork Coos River, 1983.

Chlorophyll a Concentration

mg/m^3 water

Cruise Date	Site #							
	1	2	3	4	5	6	7	Mean
4/24	-	9.88	11.11	12.96	13.58	14.82	14.82	12.86
5/8	-	20.37	17.28	15.43	20.99	19.14	19.75	18.83
5/22	-	-	41.98	30.86	22.22	23.46	25.93	28.89
6/5	-	2.84	-	4.18	-	3.13	-	3.38
6/20	-	25.97	25.15	16.83	9.79	6.36	4.31	14.74
7/2	6.84	6.12	5.22	4.67	5.04	5.04	5.04	5.42
7/20	1.94	2.99	3.73	3.28	2.39	2.24	1.94	2.64
8/1	10.85	14.14	14.15	9.91	7.55	5.66	-	10.38
8/23	-	8.93	16.14	25.98	24.82	20.89	6.78	17.26
9/28	-	3.06	2.77	3.18	2.95	2.18	1.53	2.61
Mean	6.54	10.48	15.28	12.73	12.15	10.29	10.03	11.70

to errors occurring during the extraction and calibration procedures. Chlorophyll is notoriously unstable in solution and is also difficult to extract completely from the plant cell. Furthermore, the spectrophotomic method I used for the calculations requires an excellent spectrophotometer in perfect calibration with a bandwidth of 3 nm or less (Strickland and Parsons, 1968). The Spectronic 70 instrument I used had not been recently calibrated and has a relatively wide bandwidth of 8 nm, a factor that can cause serious errors. Weber (1976) has shown that chlorophyll _a_ recovery falls drastically as bandwidth is increased. He shows a 98.9% recovery at 2 nm, 78.6% at 10 nm and 48.5% at 20 nm. These factors, combined with the fact that the whole process is an extremely time consuming one, compelled me to eliminate this procedure from my sampling regime in 1984.

Zooplankton

Mean zooplankton densities collected in 1983 are shown in Figure 5. Values for 1984 are shown in Figure 6. Densities given are transect means of zooplankters/l of water calculated from the stations sampled at each transect. Raw data for 1983 and 1984 (transect mean densities) is shown in Appendices B and C respectively.

Copepod densities are summarized into three divisions; total adult harpacticoids, total adult calanoids, and total copepodite and nauplii stages of both orders. Chironomidae larvae, as well as plecopteran, odonatan and ephemeropteran larval forms were combined with cladocerans, ostracods, polychaetes, hydrozoans, and brachyuran

Figure 5. Transect mean zooplankton densities on the South Fork Coos River from May 4 through July 3, 1983.

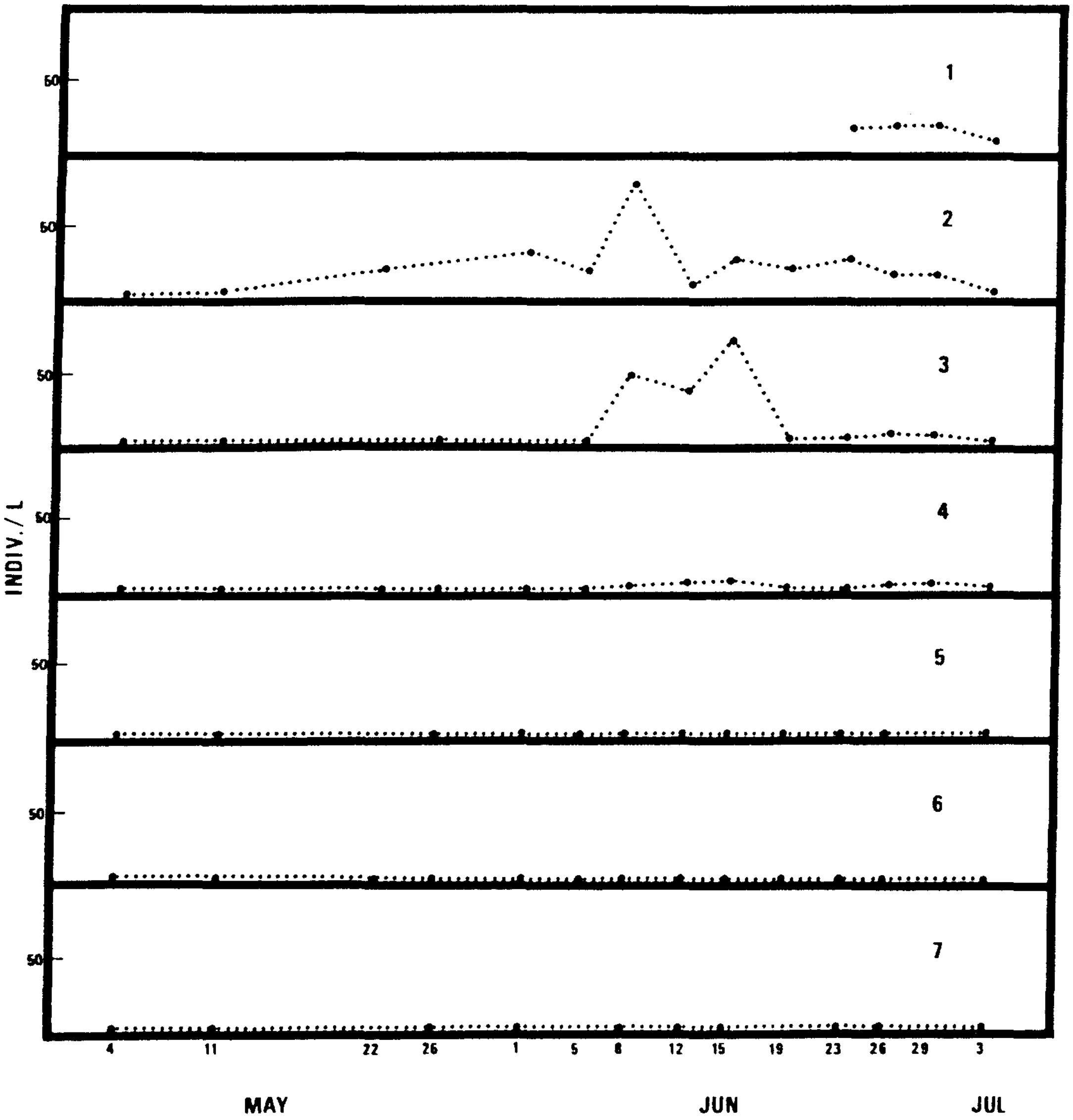
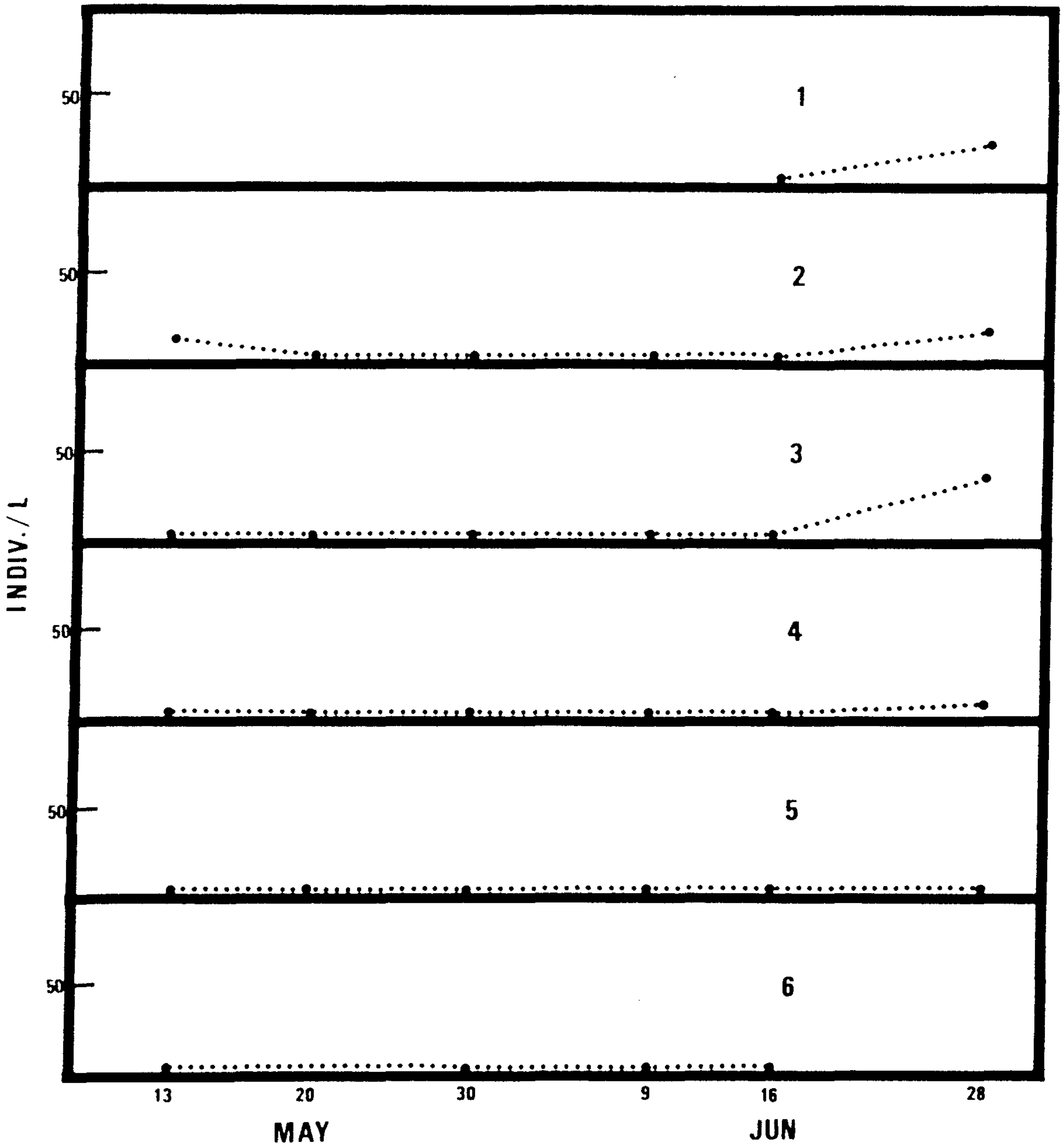

INDIV./L
50
1
2
3
4
5
6
7
4
11
22
26
1
5
8
12
15
19
23
26
29
3
MAY
JUN
JUL

Figure 6. Transect mean zooplankton densities on the South Fork Coos River from May 13 through June 28, 1984.


INDIV./L
50
50
50
50
50
50
1
2
3
4
5
6
13
20
30
9
16
28
MAY
JUN

zoea into one sample category listed as "others".

Two families of harpacticoids were found; Canuellidae and Ectinosomatidae. The only species from the family Canullidae that has been identified from the Pacific northwest is Canuella canadensis. The copepods belonging in the family Ectinosomatidae are probably members of either the genus Pseudobradya or Bradya. Three species of calanoid copepods were identified; Acartia clausi, a common estuarine and coastal form, Eurytemora americana, a common inhabitant in mid-estuary during spring and fall, and Pseudodiaptomus spp., calanoids found in freshwater.

Zooplankton densities were highly variable within the study area, from sampling date to sampling date, during both years. The mean number of zooplankters found ranged from 61.3 to 21,274.2/m^3 of water in 1983 and from 0 to 15,483.6/m^3 in 1984, with densities typically occupying the low sides of the respective scales. For all sampling dates, zooplankton mean densities were 6,731.0 animals/m^3 in 1983 to 3,030.5 animals/m^3 in 1984.

Copepodite and nauplii stages of copepods were the most abundant category of zooplankters in both years accounting for 76.6% of the total catch in 1983 and 78.9% of the total catch in 1984. Mean densities of copepodites and copepod nauplii were much higher in 1983 than in 1984, and densities peaked much earlier in 1983 than in the following year; peak densities were recorded on June 8 in 1983 when a transect mean of 17,387 animals per m^3 were sampled while the peak density in 1984, a transect mean of only 12,000 animals per m^3, was not observed until June 28 of that year.

The second most abundant group of zooplankters were the harpacticoid copepods which made up 20.3% of the catch in 1983 and 16.5% of the total in 1984. Again, mean values were much higher in 1983 than in 1984. Peak harpacticoid mean densities of 3,856.7 animals/m^3 in 1983 and 2,790.2 animals/m^3 were observed on the same respective dates each year as were the peak densities of the nauplii and copepodite stages.

The third most numerous group were the calanoid copepods, comprising 1.3% of the total in 1983 and 4.6% of the total in 1984. The calanoids appeared later than the harpacticoids and were far fewer. The peak transect average densities were recorded for both years on nearly the same date. 1,055 animals per m^3 were taken on June 29, 1983 while the peak in 1984 was an average density of 693 animals per m^3 measured on June 28, 1984.

All other taxa were lumped into one category which made up 1.8% and 0.02% of the total zooplanlton community sampled in 1983 and 1984 respectively. The major component of this category was chironomid larvae, as well as several other larval insect forms and some small pelagic polychaetes. Other groups recorded, though rarely, included hydrozoans, cladocerans, and ostracods.

Mean zooplankton densities were highly variable between sampling dates during both years but densities from transect to transect on a given date were more predictable with the highest densities typically found in the lower half of the study area while lower values were common in the upper sites. Since the number of transects that were sampled in 1983 varied from date to date two analyses were made. The first one compared the variation between transects on dates when all seven transects were sampled. Although this occurred only three times, the mean zooplankton densities were found to be significantly higher in the lower half of the study area (Friedman 2-way ANOVA; $n=7$, $X^2=16.3$; $p<0.01$). The second analysis compared transects two through six which were sampled concurrently on eleven occasions. Again, significantly higher densities of zooplankton were present in the lower half of the estuary ($n=5$, $X^2=32.1$; $p<0.001$). Similar analyses on the data from 1984, which was a much smaller sample size ($n=6$), yielded insignificant results.

Zooplankton densities at the transect level also followed a general pattern, with bottom densities typically much higher than surface densities. In 1983 mean zooplankton densities on the bottom were significantly higher than those at the surface (Wilcoxon, Matched Pairs Signed Rank; $n=54$, $p<0.001$). In 1984, there were only 11 pairs of surface to bottom densities recorded other than cases when both values were zero with a non-significant P value of 0.13. The surface to bottom gradient was present but the magnitudes of the differences were not high enough to obtain a significant result from the test.

The highest transect zooplankton density observed during the two sampling years was recorded at transect two on June 8, 1983, when a transect mean density of 77,709 animals per m^3 was recorded. Transect two also had the highest mean density of zooplankters for 1983 when an average density of 19,620 animals/m^3 were recorded there followed by transect three which had a mean density of 13,763 animals/m^3. Transect one had the highest mean density in 1984 when 10,625 animals/

m^3 were observed followed by transect two which had a yearly mean of 4,552 animals/m^3.

Ichthyoplankton

Ichthyoplankton data for 1983 and 1984 is shown in Appendices D and E respectively.

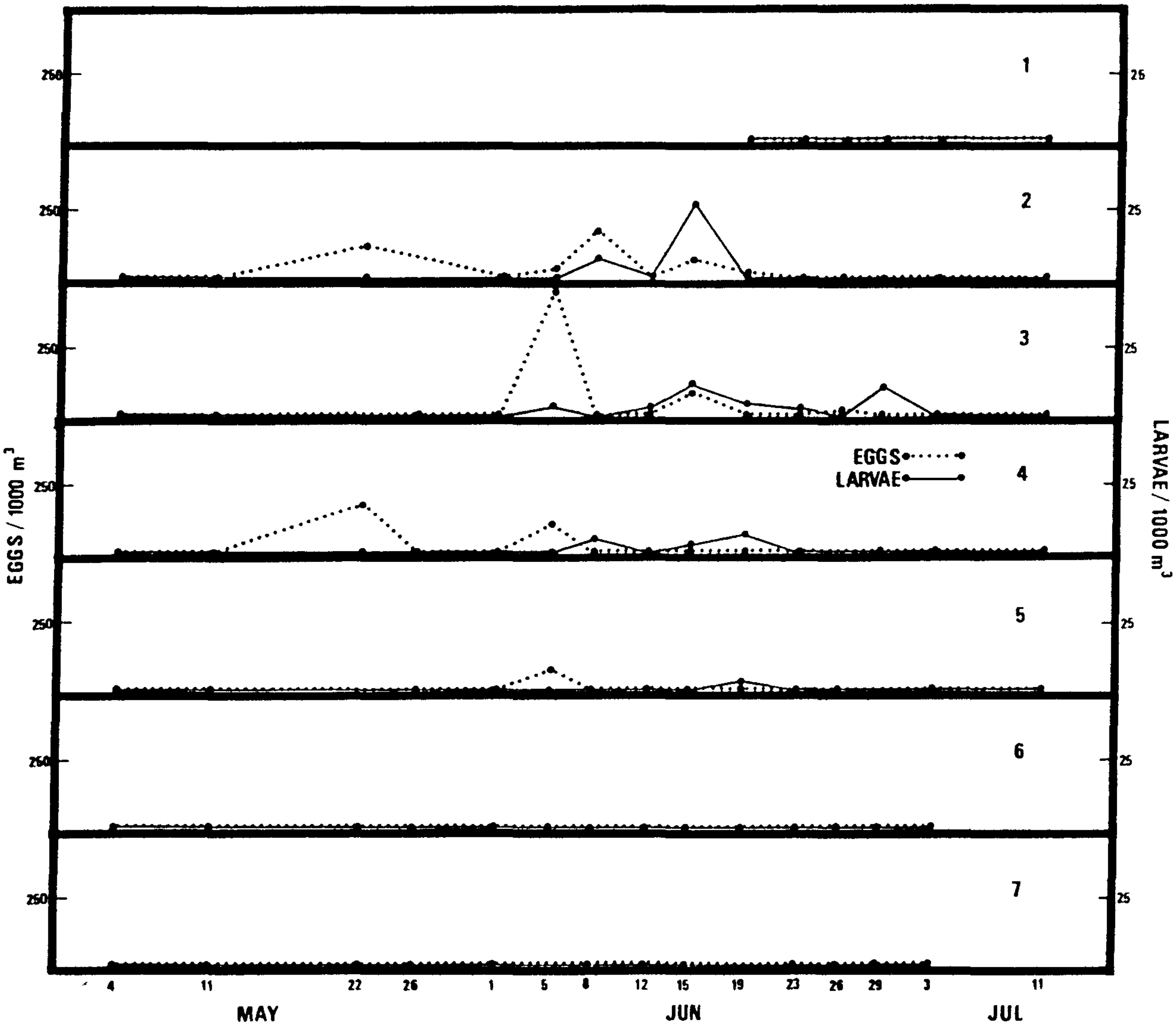
Eggs and larvae of three species were collected; striped bass, *Morone saxatilis*, American shad, *Alosa sapidissima*, and bay goby, *Lepidogobius lepidus*. Larvae only were collected of the species *Cottus asper*, the prickly sculpin.

Striped Bass Eggs And Larvae

Striped bass egg counts were very erratic within the study area during the two sampling seasons and differed markedly between the two years. Striped bass larval counts were extremely low for both years.

In 1983, a total density of 1,359 striped bass eggs/1,000 m^3 were collected in the 87 transects sampled for an average of only 15.6 eggs/1000 m^3/transect for the season (Figure 7). The first major spawn was observed on the nights of May 27th and 28th by Oregon Department of Fish and Wildlife biologists who were in the area gillnetting for broodstock fish being used in an experimental striped bass enhancement project that was in progress at the time. My sampling during that time period, conducted on May 26 and not again until June 1, completely missed this activity with no eggs or larvae taken on either of those dates. A second much smaller spawning pulse was reflected in my sampling effort on June 5 when a transect average

Figure 7. Transect mean striped bass egg and larval densities on the South Fork Coos River in 1983. Note the ten-fold difference in scale between egg and larval densities.

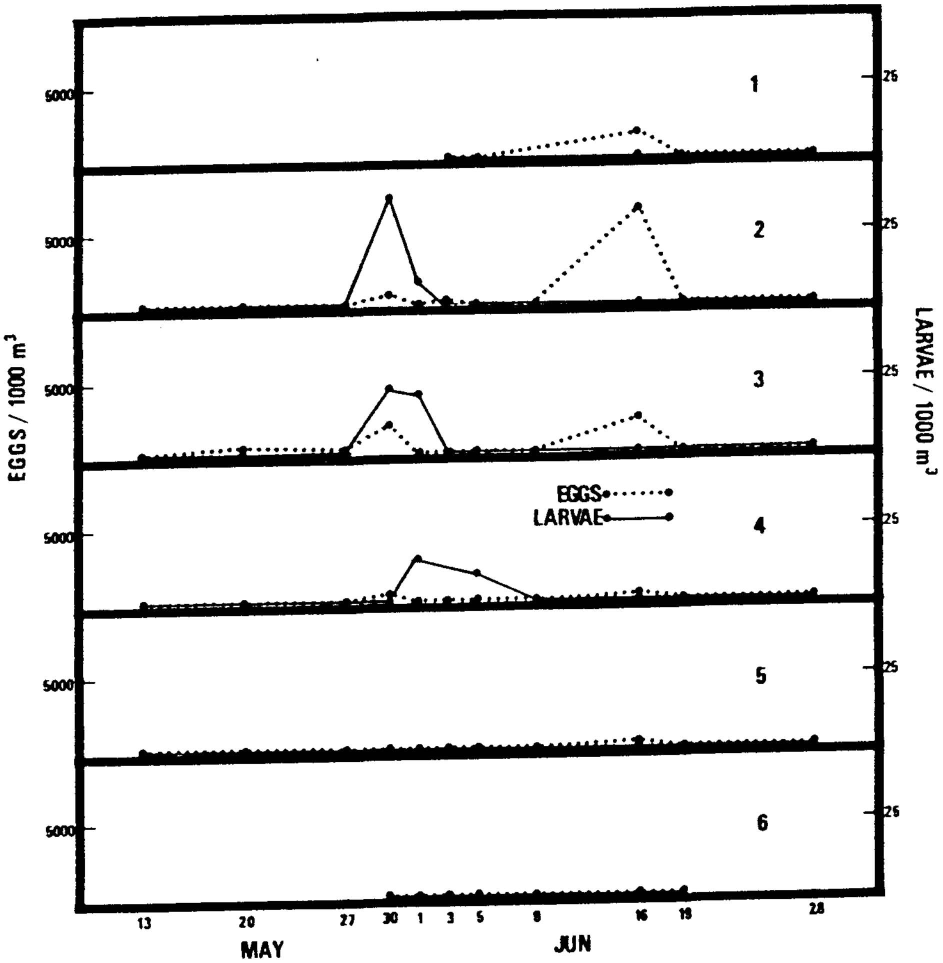

1
2
3
4
5
6
7
250
25
EGGS
LARVAE
EGGS / 1000 m3
LARVAE / 1000 m3
4
11
22
26
1
5
8
12
15
19
23
26
29
3
11
MAY
JUN
JUL

of 140.8 striped bass eggs/1,000 m^3 was recorded. Spawning activity tapered off after that with low egg densities or zero egg counts recorded for the rest of the sampling period.

In 1984, a total density of 15,401 striped bass eggs/1,000 m^3 were collected at the 56 transects sampled for an average of 275.0 eggs/1,000 m^3/transect for the season (Figure 8). This higher average probably does not indicate an increased incidence of spawning in 1984, rather, I feel it reflects a more accurate and timely sampling of the spawning that actually occurred. Two major periods of spawning activity were recorded; the first was on May 30 when a transect average of 651.0 eggs/1,000 m^3 were collected at transects two through six and the second was on June 16 when a transect average from all six transects of 1,850.0 eggs/1,000 m^3 was measured. Spawning activity on all other sampling dates, as indicated by the presence of striped bass eggs in the samples, was either very low or non-existent.

Striped bass eggs were collected on 7 of the 15 cruises in 1983 and on 6 of the 11 cruises in 1984. Striped bass eggs were confined to transects two through five in 1983. 42.9% of the eggs taken were from transect three followed by 30.0% at transect two, 21.6% at transect four and 5.5% at transect five. Egg distribution was more widespread in 1984 when eggs were found in all six transects sampled that year. Transect two had the highest proportion of eggs with nearly half the total sampled (48.7%) taken there. Transect three had 31.6% of the eggs followed by 11.2% at transect one, 5.2% at transect four, 2.9% at transect five and 0.3% at transect six. Egg distribution within the study area showed no significant patterns

Figure 8. Transect mean striped bass egg and larval densities on the South Fork Coos River in 1984. Note the two hundred-fold difference in scale between egg and larval densities.


EGGS / 1000 m³
LARVAE / 1000 m³
5000
25
1
2
3
4
5
6
EGGS
LARVAE
13
20
27
30
1
3
5
8
16
19
28
MAY
JUN

either year. No significant difference between surface and bottom egg densities were found in 1983 but in 1984 bottom egg densities were significantly higher than those on the surface (Wilcoxon; n=17, $p<0.05$).

In 1983, a total density of only 81 yolk-sac larvae and 16 post yolk-sac (finfold) larvae/1,000 m^3 were collected at the 87 transects that were sampled that year for an average of only 1.11 larval striped bass/1,000 m^3/transect for the season (Figure 7). Catch/unit effort was nearly twice 1983's level in 1984 when 104 yolk-sac and 10 post yolk-sac larval striped bass/1,000 m^3 were taken at the 56 transects sampled for an average of 2.04 fish/1000 m^3/transect (Figure 8). "Peak" abundance of larval striped bass was recorded on June 15 in 1983 when a transect average of 7.3 fish/1,000 m^3 was observed. Transect averages for the other sampling dates were typically much lower though, ranging from 0 to 2.7 fish/1,000 m^3. The highest abundance of larval striped bass in 1984 occurred on May 30 when a transect average of 12.0 fish/1,000 m^3 was observed. Larval bass were found on only two other occasions this season; on June 1 when a transect average of 8.8 fish/1,000 m^3 was observed and on June 5 when an average of 6.7 fish/1,000 m^3 was recorded.

Larval striped bass were caught in 4 of the 7 transects sampled in 1983; 42.3% at transect three, 36.1% at transect two, 17.5% at transect four and 4.1% at transect five. A similar distribution was observed in 1984 when 41.2% of the larval fish were caught at transect two, 37.7% at transect three and 21.1% at transect four. No significant differences between transects were detected, though, for either year and there was also no significant difference in the vertical distribution of the larval striped bass.

Eggs And Larvae Of Other Fish Species

Eggs were collected from two other pelagic spawners; the American shad and the bay goby. In 1983, bay goby eggs were the most abundant collected with a transect average for the season of 53.6 eggs/1,000 m^3 compared to the transect averages of 20.0 and 15.6 per/1,000 m^3 observed for shad and striped bass eggs, respectively. Striped bass eggs were the most abundant in 1984 when a transect average for the season of 275.0 eggs/1,000 m^3 was recorded compared to an average density of 41.5 eggs/1,000 m^3 for the American shad. Bay goby eggs were the least abundant this year with an average transect density of 31.7 eggs/1,000 m^3.

Shad eggs were collected on 13 of the 15 cruises in 1983 and on all 11 cruises in 1984. Average cruise densities were rather low, ranging from 0 to 52.8 eggs/1,000 m^3 in 1983 and from 0 to 141.2 eggs/1,000 m^3 in 1984. The highest transect density recorded for the two sampling seasons was 452 eggs/1,000 m^3 observed on June 5, 1984. The mean seasonal average density of shad eggs collected in 1984 was more than twice that sampled in 1983.

Bay goby eggs were collected on 5 of the 15 cruises in 1983 and on 1 of the 11 cruises in 1984. The eggs appeared in high densities in the latter part of both sampling seasons. The average cruise density for the five times goby eggs were collected in 1983 was 141.0 eggs/1,000 m^3 while an average density of 355.4 eggs/transect was recorded on the one date goby eggs were collected in 1984. Peak transect densities of 3,330 and 980 eggs/1,000 m^3 were recorded at transect one for 1983 and 1984, respectively.

Shad eggs were collected at transects two through seven in 1983 and at transects one through six in 1984. In 1983, significantly higher densities of eggs were found in transects three through five (Friedman 2-way ANOVA; $n=7$, $X^2=12.9$; $p<0.05$). 1984 shad egg densities showed no significant differences between transects. No significant difference between surface and bottom egg densities was found either year.

Bay goby eggs were collected only at transects one and two in both years. In 1983, the vast majority (99.8%) were collected at transect one while in 1984 55.0% of the eggs were taken there.

Three species of larval fish were collected besides striped bass including American shad, prickly sculpin, and bay goby. In 1983, larvae of the bay goby were the most abundant sampled with an average transect density of 92.8/1,000 m^3 for the season; prickly sculpin larvae were second in abundance with an average transect density of 30.4/1,000 m^3 followed by shad larvae with a density of 9.8/1,000 m^3 and striped bass larvae with an abundance of 1.1/1,000 m^3. In 1984, prickly sculpin larvae were the most abundant with an average transect density of 67.5/1,000 m^3 for the season followed by bay gobies, shad and striped bass with respective abundances of 21.0, 12.1 and 2.0/1,000 m^3 for the year.

Shad larvae were collected on 12 of the 15 cruises in 1983 and on 9 of the 11 cruises in 1984. Average cruise densities ranged from 0 to 48.8 larval shad/1,000 m^3 in 1983 and from 0 to 28.8/1,000 m^3 in 1984. The highest transect average for the two sampling seasons was 139 larval shad/1,000 m^3 on June 12, 1983. Seasonal mean transect averages of 9.8 and 12.1 shad/1,000 m^3 were observed for 1983 and 1984 respectively.

Prickly sculpin larvae were collected on 10 of the 15 cruises in 1983 and 10 of the 11 cruises in 1984. Average cruise densities ranged from 0 to 181.3/1,000 m^3 in 1983 and from 0 to 487.3/1,000 m^3 in 1984. The highest individual transect density of 805 sculpin larvae/1,000 m^3 was observed on May 13, 1984. Average sculpin densities were twice as high in 1984 as they were in 1983.

Bay goby larvae were collected on 10 sampling dates in 1983 and on 2 occasions in 1984. Average cruise densities were as high as 293.4 fish/1,000 m^3 in 1983 and up to 487.3 fish/1,000 m^3 in 1984. The highest transect density recorded was 1,162 larval fish/1,000 m^3 on June 26, 1983. Average bay goby densities in 1983 were more than four times greater than those in 1984.

Shad larvae were collected at transects one through six in both years. The Friedman two-way ANOVA revealed no significant differences in distribution between transects for either year. The Wilcoxon match-pairs test showed no significant surface to bottom density differences in 1983 but did show that bottom densities in 1984 were significantly higher than surface densities ($p<0.001$) for the year.

Prickly sculpin larvae were found at transects two through seven in 1983 and at transects one through six in 1984. Again, no significant variation between transects was discovered for either sampling season. Highly significant results were obtained, however, for the Wilcoxon test which showed bottom densities significantly higher than surface densities for both years ($p<0.001$ in 1983 and 1984).

Bay goby larval distribution was limited to transects one through three in both years. The Friedman ANOVA revealed significantly higher densities at these transects in 1983 ($p<0.05$) but did not reveal any significant differences in 1984, probably due to the small sample that was tested. Bottom densities were significantly higher than surface densities in 1983 (Wilcoxon $p<0.05$) but no significant difference was detected in 1984.

Juvenile Fish

Information on the abundance and distribution of juvenile striped bass and American shad was obtained from the Oregon Department of Fish and Wildlife in conjunction with their annual recruitment seining surveys conducted in the study area. All of the data presented in this section was tabulated and summarized by Reese Bender, Assistant District Biologist for ODFW, in a fisheries informational report currently in press for that organization (Bender, 1984).

Striped Bass Abundance And Distribution

A population estimate of the wild striped bass juveniles in the Coos River was facilitated in 1983 through a mark-recapture program that was conducted by ODFW. On August 15-18, 1983, 6,647 hatchery reared, marked juvenile striped bass were released in the South Fork

Coos river on August 15-18, 1983. The release was distributed by boat from the forks just above transect two throughout the river to transect seven.

A total of 190 juvenile striped bass were sampled in forty seine hauls during four seining sessions in late August, September and early October (Table 5). Of these, 167 or roughly 88% were marked fish from the August release. Population estimates were made for the two sampling periods, August 25-26 and September 7-9, when the majority of the juveniles were caught and for the combined sample of those two dates using the Petersen estimates;

$$N = \frac{(M)\ (C+1)}{(R+1)}$$

where M is the number of marked fish at large, C is the catch in each sampling period and R is the number of marked recaptures (Table 6). Upper and lower confidence limits were calculated using the Clopper-Pearson graph.

To estimate the wild unmarked segment of the population, the percentage of unmarked individuals (23/190 or 12.1%) in the total 1983 sample (mid-August to mid-October) was multiplied by the population estimate for that year (7536) resulting in a wild recruitment estimate of 912 fish for 1983. To estimate wild recruitment in other years, the average catch-per-seine haul of 0.30 wild juveniles, calculated from the standard sets taken in 1983 (not including 16 extra seine hauls conducted that year), was divided into the population estimate for 1983 (912) to obtain a conversion factor estimate of 3040 wild fish for 1.0 unit of catch/effort. This factor was then multiplied by

Table 5. Recovery of juvenile striped bass in the Coos River system, 1983.

Sampling Dates	Seine Hauls	Marked Juveniles	Unmarked Juveniles	Total
August 24-26	17	57	11	68
September 7-9	17	84	8	92
September 22-23	2	8	3	11
October 6	4	18	1	19
Totals	40	167	23	190

Table 6. Population estimates of juvenile striped bass in Coos River, 1983.

Recovery Dates	Number Sampled(C)	Number Marked(R)	Population Estimate(N)	95% Confidence Limits	Wild Population Estimate*
Aug 25-26	68	57	7908	Nu=9232 Nl=7225	
Sept 7-9	92	84	7273	Nu=8106 Nl=6997	
Combined Samples	160	141	7536	Nu=7071 Nl=8008	912

* Percentage of wild fish caught in all seining done (23 of 190 or 12.1%) multiplied by the population estimate.

the catch/effort of juvenile striped bass in 1978 through 1984 to obtain the estimated wild recruitment for those years (Table 7).

The estimated population in 1984 of 1003 wild fish is not significantly different than the 1983 estimate, and both years represent a near total lack of recruitment success. The only year, of those for which population estimates were made, that does exhibit some degree of successful recruitment was 1978, when an estimated 8790 juveniles were recruited to the system.

The majority of the juveniles found during the two years were in the South Fork Coos side (83.8%) and the majority there were found at site six (38.9% in 1983 and 46.1% in 1984) followed by sites two and three in 1983 and by sites three and five in 1984 (Table 8). No wild juveniles were found in the Millicoma River in 1983 and only 6 were found there in 1984, five of those at site 10.

American Shad Abundance

Juvenile American shad were extremely abundant during both years, in both the South Fork Coos and Millicoma rivers (Table 9). Catch/effort was 100.5 fish/seine haul in 1983; for every one striped bass juvenile there were 335 American shad. The ratio was even more skewed in 1984 when the catch/effort of juvenile shad was 193.4 shad/seine haul for a ratio of 585 shad taken per single striped bass.

Table 7. Estimated recruitment of wild juvenile striped bass in the Coos River, 1978-1984.

Year	Number Of Sets	Number Of Fish	Catch/ Effort	Estimated Population
1978	46	133	2.89	8790
1979	42	6	.14	434
1980	49	0	.00	0
1981	60	0	.00	0
1982	60	13	.22	659
1983	60	18	.30	912
1984	58	19	.33	1003

Table 8. Numbers and sizes of wild juvenile striped bass seined in the Coos River system in 1983 and 1984.

1983				1984			
Sampling Dates	Site #	Juveniles Seined	Ave. Size	Sampling Dates	Site #	Juveniles Seined	Ave. Size
7/27-7/28	3	1	32.00	7/31-8/1	5	1	23.00
8/9-8/10	2	5	55.00	8/13-8/14	2	1	43.00
	5	1	47.00		3	2	45.00
	6	1	55.00				
				8/28-8/29	3	1	65.00
					5	1	61.00
8/24-8/25	3	2	76.50		6	4	74.75
	6	5	72.80		10	5	67.40
9/7-9/8	-	0	.00	9/10,9/12	3	1	108.00
					6	1	88.00
9/22-9/23	2	1	118.00		9	1	105.00
	3	1	113.00				
	6	1	100.00	9/26-9/27	6	1	123.00
Totals		18				19	

Table 9. Catch of juvenile American shad during recruitment surveys in the Coos River system, 1978-1984.

	Millicoma River		S. F. Coos River		Combined		
Year	Seine Hauls	Catch	Seine Hauls	Catch	Seine Hauls	Catch	Catch/Seine
1978	23	1,713	23	3,169	46	4,882	106.1
1979	21	2,065	21	3,707	42	5,772	137.4
1980	23	1,907	26	7,519	49	9,426	192.4
1981	25	1,913	35	8,551	60	10,464	174.4
1982	25	784	35	4,297	60	5,081	84.7
1983	25	650	35	5,378	60	6,028	100.5
1984	23	1,950	35	9,270	58	11,220	193.4

CHAPTER IV

DISCUSSION

Hydrographic Parameters

The first question I will address in this discussion will concern the physical conditions in the Coos River during the striped bass spawning seasons and how these conditions might have affected egg and larval survival.

Temperature

Water temperature at the time of spawning and during the egg and larval incubation stages is one of the most important physical factors influencing the ultimate recruitment success of striped bass. Rapid changes in water temperature during a critical developmental period can moderate or virtually destroy the production of striped bass during a particular year (Dey,1981). The vulnerability of striped bass to catastrophic events is very high because most of the year's production of eggs and larvae often occurs over a short time (Kernehan, *et al.*, 1981). This vulnerability is amplified with the small Coos River population of striped bass because they typically all spawn in one or two narrow time periods.

The onset of striped bass spawning is temperature dependent, apparently triggered by a noticeable increase in water temperature

(Setzler, et al., 1980). Water temperatures of 14-15 °C are usually sufficient to induce spawning (Westin and Rogers, 1978).

Numerous studies have been conducted on the temperature requirements for developing eggs. Morgan and Rasin (1981) found that survival of striped bass eggs was optimized at temperatures between 16 and 23 C. Rogers et al. (1977) reported that eggs incubated at temperatures below 12 C rarely survived to hatching while the upper critical limits of egg survival ranges from 22.2 C (Barkuloo, 1970) to 27 C (Morgan and Rasin, 1983).

Temperature ranges for larval survival is 10-25 C (Davies, 1970), increasing to 4.4-35 C as the larval fish metamorphose into juveniles. Optimal temperature values for survival are 16.6-18.3 C (Bayless, 1972). Rogers et al. (1977) found that while yolk-sac larvae can successfully survive temperatures as low as 12 C, the larvae do not feed and thus die without growing larger than 5-6 mm TL. Cox and Coutant (1981) found that growth rates and food consumption rates were greatest at 25 C, while appetite appeared to be depressed at higher temperatures, and the ability to capture prey was impaired. These effects were particularly evident for individuals held at temperatures above 33 C. Morgan et al. (1981) found 15-25% of the larvae raised in the temperature range of 20-22 C and higher showed yolk depletion and abnormal rates of development plus some variation in morphology. Higher temperatures appeared to be responsible for the production of pugheaded striped bass.

Spawning in the Coos River in 1983 and 1984 was closely correlated to increasing river temperatures (Figure 4). Spawning occurred both years as temperatures reached 18-19 C, a value somewhat higher than typically observed in other river systems. Only one major spawning peak was observed in 1983 which was correlated with a two week warming trend when water temperatures went from 13.1 C to 20.1 C. Spawning in 1984 was bi-modal with the two major peaks occurring as rising water temperatures exceeded 18 C.

The one major spawn in 1983 was followed by a rapid drop in water temperature. Temperatures plunged from 20.1 C, measured on the second day of the major spawn (May 28), to 15.8 C five days after that (June 2). Using the regression:

$$I = -4.60\ T + 131.6$$

where I = development time to hatching, in hours and

T = degrees C (Polgar et al., 1976),

to calculate the hatching time for these eggs and the average temperature measured from May 28 through June 1 (18.9 C) results in a hatching time of approximately 44 hours or just under two days. Sampling conducted on June 1 (the fourth day after spawning) failed to turn up a single striped bass larvae, at a time when they should have been at a peak. This observation leads me to conclude that this rapid temperature drop could have been a major cause of mortality of these eggs. Spawning activity for the rest of the season was quite limited but eggs spawned during this time were generally exposed to more favorable temperature conditions.

Temperature conditions for the few larval fish that were in the river in 1983 were very good; the average water temperature in June was 18.1 C, a value within the optimal range for larvae.

The first major spawn in 1984 was also followed by a rapid decline in water temperature; temperatures at spawning of 18.3 C were followed by water temperatures of 12.2 C only eight days later. Larval abundances in the first two weeks of June were extremely low, again leading me to the conclusion that high egg mortality could have resulted from the depressed temperatures in the area. The second major spawn, observed on June 16, was followed by more favorable temperature conditions; average temperatures for the last two weeks of June were 19.4 C, a value well within the optimum for both egg and larval survival.

Egg And Larval Transport

Striped bass are pelagic, broadcast spawners; their eggs are semibuoyant with an average specific gravity of 1.0005. Being heavier than water, the eggs need a slight current to keep them suspended in the water column; eggs that settle to the bottom rarely hatch. Minimal flow rates for egg development should be at least 0.3 m/sec (Albrecht, 1964). Since striped bass eggs normally take 2 days to hatch, about 52 km of water flowing at 0.3 m/sec would be required to suspend the eggs throughout development. Whether this water movement is in one direction, as in a freshwater stream, or in two directions, as is the case of a tidal stream such as the Coos River, is unimportant as long as the eggs remain suspended in the water column.

Upper flow rate limits are also an important factor affecting egg development, especially in a small estuarine system such as the Coos. Aside from the direct cooling effects high flows can have on the spawning grounds, there is also the problem of elevated flushing rates (non-tidal-drift) which increase the probability that the eggs are moved out of the spawning grounds altogether into areas of the estuary that are unsuitable for egg development.

Striped bass larvae, unlike the planktonic eggs, are better able to maintain their position in the water column during periods of high flow through several behavioral adaptations. The first of these is a vertical migration the larval fish make in response to being negatively phototrophic; larval fish move to the darker, deeper and slower moving waters during periods of daylight (Norcross and Shaw, 1984). The second, and perhaps more direct response the larval fish exhibit to avoid downstream displacement is their orientation into water currents; tests have shown that larval striped bass react to entraining flows with vigorous swimming upstream (Starnes, et al., 1983). Both of these adaptations serve to help the larval fish maintain their position within the nursery area during their early development.

Spawning success in both sampling years in the Coos River was hampered by high flow rates; either by the temperature depression associated with high flows as discussed in the previous section, or by the high flushing rates associated with high flow conditions. The rate of non-tidal-drift through the study area at the time of striped bass spawning is crucial to egg and larval survival due to the proximity of the nursery area to upper Coos Bay where water conditions are unsuitable for rearing. Transect one, at the lower boundary of the spawning grounds, is only 4 km from the mouth of the Coos River.

The majority of the spawning activity in 1983 was observed in transects two through four which are approximately 6.4 to 11.2 km respectively from the mouth of Coos River. The one major period of spawning in 1983 was accompanied by non-tidal-drift rates averaging 8.5 km/day during the two days of peak spawning and three days after that (May 27-31). With hatching time just under two days it is likely that many of these eggs were flushed completely out the nursery area and did not survive as a result.

Spawning activity in 1984 was bi-modal, with peaks measured on May 30 and June 16. Non-tidal-drift rates were again quite high during both of these periods. Average rates for May 30 through June 2 were 6.65 km/day; the average for June 16 through June 20 was much higher at 11.55 km/day. Spawning activity was again concentrated in transects two through four so it was quite likely that many of the eggs spawned during the two periods of activity were flushed out of the nursery area before hatching could occur. This was particularly evident during the second major spawn on June 16; sampling that date yielded a transect average of 1850 striped bass eggs/1000 m^3 followed only three days later by a total absence of eggs or larvae. An obvious explanation is that the eggs were carried completely out of the study site by the high non-tidal-drift rates.

Turner and Chadwick (1972) found a significant relationship between abundance of young striped bass and river flow rates in the Sacramento-San Joaquin estuary between 1959 and 1970. Higher recruitment was associated with higher flow rates in the estuary. They propose six possible mechanisms that may explain how the high flows favor striped bass recruitment. Setzler-Hamilton *et al.* (1977) demonstrated that dominant year classes of striped bass of the Potomac

River occurred during similar times; namely those years preceded by colder than normal winters and greater than normal spring flows.

Past evidence available for the Coos River striped bass and my sampling efforts in 1983 and 1984 indicate a scenario contrary to the one that is evident for other populations of striped bass. Dominant year classes in Coos Bay seem to be associated with lower than normal flow rates in the river/estuary as opposed to higher than normal flows associated with dominant year classes in other systems.

Based on age composition data, dominant year classes occurred in Coos River in 1940 (Morgan and Gerlach, 1950), in 1951 (McGie and Mullen, 1979) and in 1958 (Breuser, 1964). The 1940 year class was probably the largest produced in the history of striped bass in the system. Average flow rates for May through July were calculated for the South Fork Coos River for the years 1929 through 1960. Comparing the years of dominant year classes with the mean flow rates for the spawning and rearing periods of those years reveals a pattern of successful recruitment during years of lower than mean flow rates (Table 10).

Although the data indicate that dominant year classes occur only during years with lower than mean flow rates in May through July, a causal relationship between recruitment and flow rates alone cannot be established. An attempt was made to correlate year class strength with flow rates during the spawning season of that year using commercial fishery records for striped bass from 1931 to 1975 and flow data for the same years. Using the assumption that the majority of the fish recruited to the nets were age 5 (McGie and Mullen, 1979), I compared recruitment (catch/net in kilograms offset five years) with the flow

Table 10. Average flow rates for May, June and July; South Fork Coos River, 1929-1960.

Year	Mean Flow
1929	7.26
1930	8.50
1931	2.84
1932	8.09
1933	29.65
1934	4.83
1935	5.62
1936	7.94
1937	25.96
1938	8.20
1939	2.48
1940*	7.70
1941	10.42
1942	16.37
1943	10.14
1944	8.83
1945	11.52
1946	4.29
1947	9.91
1948	15.82
1949	11.21
1950	8.88
1951*	8.23
1952	7.66
1953	29.57
1954	5.06
1955	11.40
1956	7.95
1957	9.23
1958*	5.21
1959	4.07
1960	21.04
Mean Flow 1929-1960	10.50

* Dominant Year Class Year

conditions for the respective years and found no significant correlation between the two. A better approach to this analysis would be to compare the length frequencies of the catch with the flow rates, rather than weight statistics/net fished. This type of approach would more accurately assess the age composition of the catch and hence the recruitment success for the particular year and would perhaps result in a significant correlation. The lack of these types of data has, unfortunately, prohibited any further analysis of this hypothesis.

Salinity

The presence of saline water plays a less important role in striped bass spawning success. This fact is exemplified by the many healthy, reproducing populations of striped bass in landlocked watersheds. Some 38 states have sucessfully established freshwater striped bass fisheries (Combs, 1980). Most of these fisheries are supported by stocking, but populations supported by natural reproduction have been reported in Santee Cooper Reservoir, South Carolina; Kerr Reservoir, Virginia/North Carolina; Millerton Lake, California; Keystone Reservoir, Oklahoma and Lake Mead, Arizona/Nevada (Gustaveson, et al., 1984).

Striped bass are anadromous fish and spawn in fresh or nearly fresh waters (Setzler, et al., 1980). The optimal salinity range for striped bass egg development is from 1.5-3 ppt although 0-10 ppt is tolerable (Doroshev, 1970). Lal et al. (1977) reported that survival of eggs hatched in salinities ranging between 10 and 50% sea water (3.2-16 ppt) was higher than in fresh control water. Larval striped bass can tolerate salinities up to 15 ppt but optimal salinities are from 5-10 ppt (Doroshev, 1970). Lal et al. (1977) found that a program of progressive increases in salinity from 10-100% enhanced both survival and growth of striped bass. Related work at UC Davis showed significant increases in larval survival associated with brackish water culture (Van Olst, et al., 1980). These researchers found that salinities of 10-12 ppt resulted in more dramatic reductions in larval mortality than any other factor investigated.

Salinities were low during both spawning seasons. Freshwater was recorded at all transects through June 5 in 1983 resulting in freshwater incubation for the majority of the eggs spawned. Salinities increased gradually at the lower transects during the remainder of June but rarely exceeded 5 ppt at any transect other than number one, thereby limiting areas of optimal salinity for any larval striped bass that may have been present.

Freshwater was recorded at all transects in 1984 through June 16, including the times of both spawning peaks. Salinities were recorded only at transects one and two during the remainder of the sampling season and only exceeded 5 ppt at transect one, again resulting in less than optimal salinity patterns for the survival of striped bass larvae.

Turbidity

Dredging and spoil disposal in the coastal zone have generated considerable concern over the effects of suspended and deposited sediments on the survival and growth of fish, particularly the egg and larval stages (Auld and Schubel, 1978). This is also a concern in the

Coos system where dredging, spoil disposal and logging keep the sediment load high throughout the striped bass spawning season.

Several studies have been conducted on the effects of various concentrations of suspended sediments on striped bass eggs and larvae. Auld and Schubel (1978) tested the effects of four different suspended sediment concentrations, 50, 100, 500 and 1,000 mg/l, on the hatching success of striped bass eggs; they found significant effects on hatching only at the 1,000 mg/l level. Larval survival was tested at the same sediment concentrations and significant effects were noted at the 500 and 1000 mg/l concentrations. These data indicate that the larval fish are slightly less tolerant to high sediment loads than are the eggs. Morgan, et al. (1983) found that high concentrations of suspended sediments had little effect on striped bass eggs or larvae. They did, however, find significant effects on eggs and larvae, especially a delay in hatch, at sediment concentrations rare in nature (1,500 mg/l for the eggs and 1,500-5,000 mg/l for larvae).

The apparent absence of measurable effects of suspended sediment concentrations normally found in even the more turbid estuaries on striped bass eggs and larvae supports the contention of Mansueti (1961) that striped bass eggs and larvae are 'pre-adapted' to a turbid estuarine environment (Auld and Schubel, 1978).

No direct suspended sediment measurements were made, rather, water transparency measurements were taken using a Secchi disk. These measurements did not permit a quantified assessment of suspended sediments present but did provide a qualitative indicator of turbidity. Transparency mean values were the same for both years averaging 1.0

meters; a value that indicates some turbidity and suspended sediments, but one that does not indicate an excessive degree of suspended sediment. This fact, combined with the resiliency of striped bass eggs and larvae to high concentrations of suspended sediments leads me to conclude that turbidity rates in 1983 and 1984 had little or no effect on recruitment success.

High turbidity levels can affect larval fish behavior though, and could possibly influence larval growth and survival rates to some degree. Matthews (1984) found that, while high turbidity is not directly lethal to fish, it can have a significant influence on characteristics of a fishery or fish behavior. Increased turbidity can depress activity (Heimstra, *et al.*, 1969), alter feeding efficiency, (Zaret, 1978) and decrease the numbers of prey seen or consumed (Gardner, 1981). Observations on Lake Texacoma showed that larval shad and freshwater drum exhibited a markedly different vertical distribution during periods of extreme turbidity (Secchi=0.2 meters); the fish were concentrated proportionally higher in the water column than before the inflow of water containing a high amount of suspended sediment (Matthews, 1984). Since larval fish are visual feeders (Hunter, 1981), the attenuation of light by turbid waters can apparently influence their vertical distribution by forcing them to shallower waters where light penetration and visibility are better.

No significant differences were seen in either year between surface and bottom striped bass larvae densities in the Coos River. This is probably due to the fact that the majority of the larvae taken were yolk-sac larvae which are essentially planktonic. Turbidity levels may have been high enough to inhibit the onset of feeding of the larval striped bass, especially given the low prey densities that were present, but this is only speculation. The effects of turbidity on egg and larval survival in the Coos system merits further study.

pH

New evidence has recently been published suggesting a strong correlation between low pH levels caused by acidified rain or runoff and low striped bass recruitment levels. Studies conducted on larval striped bass from the Nanticoke and Choptank Rivers, Maryland, in 1984 suggested that exposures to pH levels of 5.5 and below for as little as 24 hours resulted in substantial, if not complete, reductions in numbers of young striped bass (Mehrle, *et al.*, 1985). Other studies of fish reproduction have found that low pH can decrease the motility of the sperm, influence the endocrine system of the maturing female, damage the genetic material of developing ova, inhibit hormone production and activity, and skew the sex ratio of the broods toward males (Fritz, 1980, Haines, 1981 and Rubin, 1985).

Lowered pH levels are typically caused by acid rain, the result of industrial air pollution, but can be caused by acidified runoff from clear-cut timber areas. Laughlin *et al.*, (1978) compared pH levels prior to and after clear-cutting activities in a North Florida estuary and found a significant reduction in pH of approximately 0.8 units in those areas subjected to runoff from the clear-cut areas. The differences were particularly pronounced in early spring and late summer when runoff was high.

Measurements of pH were taken weekly only in 1984 when neutral to slightly basic pH levels were measured for the entire study period, suggesting that acidic conditions did not occur in the Coos River during my study. I feel, however, that this question deserves further attention and closer monitoring in the future in light of the extensive clear-cutting that has occurred, as is presently underway, in the Coos River valley. Fluctuations in pH could be more severe than my data suggest simply because my measurements were taken only once per week. Daily or hourly pH measurements taken during the striped bass spawning season would provide a more accurate and comprehensive picture of the pH conditions in the river, and would be of particular interest during periods of high runoff.

Biological Factors

In this section I will discuss the second question I asked, concerning the prey needs of the larval striped bass and the zooplankton production in the study area, to see if zooplankton abundance and distribution may have been a limiting factor to larval survival. I will then briefly address some other biological factors that, although not investigated in my study, may be affecting recruitment success in the Coos Bay striped bass population.

Larval Prey Availability

Zooplankton populations play a vital role in the larval life of striped bass and can be one of the major limiting factors of successful recruitment (Westin and Rogers, 1978, Setzler-Hamilton, *et al.*, 1980, Eldridge, et al., 1981). The presence of adequate numbers of appropriate zooplankton prey items, at the right time and in the right place, is essential for larval striped bass survival and growth.

Miller (1977) attempted to determine the minimal prey density requirements for first-feeding striped bass and estimated that a minimum prey concentration of 1864 nauplii (*Artemia*)/l was required to establish successful first feeding. Eldridge et al. (1981) hypothesized that wild striped bass larvae must find patches of zooplankters denser than 100 zooplankters/l to meet their metabolic requirements. Beaven and Mihursky (1979) estimated that densities of zooplankters which were fed upon by larval striped bass examined from the Potomac Estuary ranged from 25 to 310/l.

The high degree of variability between the results of these various studies reflects the complexity of the hypothesis. Zooplankton distributions are known to be patchy in nature. Additionally, survival of striped bass larvae in a natural setting, even under ideal conditions, is very low. These factors make it difficult to extrapolate results of laboratory feeding studies to "minimum" prey densities required by striped bass larvae in a natural setting (Setzler-Hamilton, et al., 1977).

Although the critical value or "minimum prey density" of zooplankters necessary for the onset of feeding and survival of striped bass larvae remains unclear, the fact that survival rates increase with increasing ration is well established. Daniel (1976) found that mean daily loss rates of larval striped bass varied from 10.86% for bass receiving no food to 3.22% for those receiving densities of 30 *Artemia* nauplii/l. Eldridge et al. (1981) also found decreasing daily mortality rates with increasing ration. Their results showed a 12% daily mortality for bass receiving no food decreasing to a 0.6% mortality for those fish receiving a ration of 5,000 nauplii/l. Mortality rates at prey densities of 100 nauplii/l were 2.7%.

Other researchers have hypothesized, given the patchy distribution of zooplankton in natural situations, that only those striped bass larvae that by chance encounter high density patches of suitable zooplankton prey are able to start feeding, given that these high density patches do, indeed, exist in the nursery area (Eldridge, et al., 1981).

Several analyses of larval bass feeding habits have revealed that copepods make up an important component of the diet. Heubach et al., (1963) found the copepods Pseudodiaptomus, Acartia, and Eurytemora in the stomachs of larval bass from the Sacramento River. Gomez (1970) found the copepods Cyclops and Diaptomus in the stomachs of larval striped bass examined from Canton Reservoir, Oklahoma. Meshaw found that young striped bass were highly selective for the copepod Cyclops while they selected against the cladocerans Daphnia and Bosmina. Doroshev (1970) reported similar findings; there was positive selection for all stages of Cyclops and rejection of Daphnia spp.

Zooplankton abundance levels in 1983 were, on the average, quite low and could have been a major limiting factor on striped bass larval survival, especially in the upper transects. Zooplankton densities did not exceed 1 animal/l in transects five through seven during the entire season; a density level that most surely would limit larval survival.

Conditions were somewhat more favorable in transects one through four where zooplankton abundances varied from less than 1 animal/l to more than 77 animals/l; densities still on the low side of what is thought to be necessary for survial and growth. The average transect density of zooplankton for these transects from June 1 through July 3 was only 14.6 animals/l; this is certainly not an optimal value for maximizing survival rates but presumably not a level so low as to prohibit the onset of first-feeding.

Zooplankton species composition in Coos River consisted mainly of a mixture of harpacticoid and calanoid species, among them, Acartia, Eurytemora and Pseudodiaptomus; all acceptable prey items for larval bass leading me to believe that the densities of the zooplankton present, not the species composition, were the limiting factor.

Zooplankton abundance levels in 1984 were much lower than those recorded in 1983 and could have had a severe impact on larval survival. Average transect densities were less than 1 animal/l at all transects sampled from May 20 through June 16. Mean transect densities recorded on the final sampling date (June 28) averaged only 15.4 animals/l; this is a value near the average for the entire month of June in 1983 and, almost certainly occurred too late in the season to benefit striped bass larvae.

Species composition, of the few zooplankters that were collected, was similar to that of 1983 leading me again to the conclusion that low densities, not inappropriate prey species, were the limiting factor.

No significant differences between surface and bottom striped bass larval densities were observed either year, even though zooplankton densities were consistently higher in the bottom samples. This evidence seems to suggest that the larval fish are not keying in on the highest zooplankton densities available, but the sample of post-yolk-sac, feeding striped bass was so small that an accurate assessment of their distribution as related to prey abundance is not possible.

Broodstock Health

Increasing concern has recently been centered on the effects of toxic water pollutants on the health and breeding efficiency of striped bass. Rising polychlorinated biphenyl (PCB) concentrations in striped bass of the Hudson and Chesapeake systems have caused considerable concern, even though a link between these pollutant levels and recrutiment success has not yet been shown (SFI Bulletin, 1984). Field and laboratory studies conducted by Whipple et al. (1983) have shown correlations between certain toxic pollutants and reduced reproductive capacity, fecundity and egg viability in fish from the San Francisco Bay. The health of the broodstock fish, therefore, can be an important contributing factor to the recruitment patterns that are observed.

Laboratory studies conducted by Whipple et al. (1983) on broodstock fish from the Coos River have shown that, overall, the stock is in better general health than fish from the San Francisco Bay-Delta. Coos River fish have lower tissue burdens of toxic pollutants, fewer parasites and a higher index of mean body condition. The mean fecundity value of Coos River fish was the highest of those tested and they showed the lowest percentage of resorbed eggs (in normal ovaries). The only anomalous condition that was apparent in the Coos River broodstock was a high incidence of hermaphrodism which is discussed in the next section. Toxic pollutants apparently have little, if any, effect on the recruitment success of the Coos River striped bass.

Genetic Factors

The striped bass population in Coos Bay was established when migrants from the San Francisco Bay population, which had originated from only 500 fish introduced there in the early 1880's, moved up the coast and into the bay in the early 1900's (Morgan and Gerlach, 1950). Since no known broodstock introductions have ever occurred in Coos Bay it seems safe to assume that the entire population here resulted from the successful spawning of a very small number of fish, resulting in what is probably a substantially narrowed gene pool in the broodstock.

Inbreeding has long been known to cause reductions in viability and growth and has been shown to increase the number of abnormal phenotypes in several fish species. Restrictions in the effective breeding population of a species increases the probability of inbreeding and the probability of changes in the gene frequency via genetic drift; inbreeding can, therefore, ultimately result in increased homozygosity and a genetically unstable population (Tave, 1984). Once genetic variance is lost, it may take hundreds to thousands of generations to regain it naturally (Nei _et al._, 1975).

The long term consequences of inbreeding on the reproductive success of the Coos River striped bass are unknown and merit further study, but the high numbers of hermaphrodites in the system are evidence of inbreeding and a small gene pool. Eleven of 42 adult striped bass collected from the Coos River in 1980 were hermaphrodites. This compares to only two hermaphrodites identified from more than 500 adult striped bass collected in San Francisco Bay the same year. Many of the hermaphrodites collected had adhesions blocking the ovarian ducts thus preventing the passage of eggs. However, if a functional male hermaphrodite fertilizes normal females, or if a hermaphrodite female releases some eggs, this trait can be transmitted (Moser, et al., 1983).

The narrowed genetic makeup of the Coos Bay stock may also be responsible for the "all or nothing" spawning characteristics of the striped bass here, increasing their vulnerability to the widely varying hydrographic conditions of the Coos River system in the spring and early summer. Striped bass spawning seasons in other areas, though relatively short compared to many fish species, usually last from four to eight weeks; a period of time long enough to increase the odds that at least some of the eggs will be spawned during a time of favorable environmental conditions. A "typical" striped bass spawning season in the Coos River, on the other hand, consists of one or two brief periods of frenzied spawning activity lasting no more than two or three days each; a mode of reproduction that dramatically reduces the odds that the eggs will be subjected to favorable conditions.

In contrast, the American shad have a protracted spawning season lasting two to three months in the Coos River and are typically very successful here; presumably because by spawning over a longer period of time, there is an increased probability of fertile, developing eggs meeting with favorable environmental conditions which, in turn, enhances the probability of survival.

Competition With Other Larval Species

Interspecific competition for available prey items could be a factor limiting survival rates for larval striped bass, especially when available prey densities are low to begin with. Significant numbers of prickly sculpin and American shad larvae inhabit the same nursery area as the striped bass and probably utilize similar prey species. Shad and sculpin larvae were more abundant in bottom waters, whereas striped bass showed no difference. Shad larvae outnumbered striped bass larvae 10 to 1 in 1983 while sculpin larvae were 30 times more abundant. Similar trends were evident in 1984 when shad larvae were nearly 6 times as abundant as striped bass larvae and sculpins outnumbered bass larvae 33 to 1. I made no attempt to assess the impacts of competition for available prey by these other species on the striped bass, but the potential for a negative impact was definitely present.

Summary

Two major lines of analysis were pursued in this study. The first dealt with the environmental parameters that may have an impact on striped bass recruitment success. My research confirmed the fact that the striped bass in the Coos River are extremely vulnerable to the widely varying hydrographic conditions that are common in the river during the spawning season. This was particularly evident for water temperature and flow patterns. During both years of my study, cold temperature conditions and high flushing rates at the time of spawning had a severe impact on egg and larval survival. There appears to be a correlation between low flow conditions and the production of dominant year classes in the Coos system, but this hypothesis needs further testing and investigation. The effects of the turbidity, pH, and salinity conditions in the study area were less clear cut and also merit further study; especially the impacts that log rafting and clear-cutting in the Coos system have on the recruitment success of the striped bass.

The second question I asked dealt with the biological condition of the rearing area and of the broodstock fish. I found that the zooplankton concentrations present at the time of striped bass spawning were far from optimal, and could have easily been a serious limiting factor to striped bass larval survival. The reasons behind the low zooplankton densities were not examined but were most likely correlated with the low temperature and high flow conditions that were present in the study area during both years. I also briefly examined the health of the Coos Bay striped bass and concluded that while the fish are ,in general, quite healthy and free of the effects of industrial pollution, they may have serious problems genetically. The small broodstock population and the years of inbreeding that the stock has undergone may be influencing recruitment success through a variety of mechanisms. This is a very important consideration in terms of the long range management of the striped bass and should be examined carefully in the future.

APPENDIX A

TRANSECT MEAN SALINITIES (PPT) IN THE SOUTH FORK COOS RIVER IN 1983 AND 1984.

1983

Date	Transect						
	1	2	3	4	5	6	7
May 4	-	0	0	0	0	0	0
May 11	-	0	0	0	0	0	0
May 18	-	-	-	-	0	-	0
May 22	-	1	-	0	-	0	-
May 26	-	-	0	0	0	0	0
June 1	-	0	0	0	0	0	0
June 5	-	0	0	0	0	0	-
June 8	-	3	1	0	0	0	0
June 12	-	11	2	0	0	0	-
June 15	-	8	0	0	0	0	0
June 19	7	1	0	0	0	0	-
June 23	18	2	0	0	0	0	0
June 26	18	9	1	0	0	0	0
June 29	18	4	0	0	0	0	0
July 3	3	0	0	0	0	0	0
July 1	16	4	0	0	0	-	-

1984

Date	Transect					
	1	2	3	4	5	6
May 13	-	0	0	0	0	-
May 20	-	0	0	0	0	-
May 27	-	0	0	0	0	-
May 30	-	0	0	0	0	0
June 1	-	0	0	0	0	0
June 3	0	0	0	0	0	0
June 5	-	0	0	0	0	0
June 9	-	0	0	0	0	0
June 16	0	0	0	0	0	-
June 19	2	0	0	0	0	0
June 28	17	4	0	0	0	-

APPENDIX B

TRANSECT MEAN DENSITIES OF ZOOPLANKTON (NUMBERS/M^3) IN THE SOUTH FORK COOS RIVER, 1983.

Transect	Harpacticoid Copepod	Calanoid Copepod	Copepod Nauplii	Others	Total
May 4, 1983					
1	-	-	-	-	-
2	228	0	0	17	245
3	0	0	0	0	0
4	0	0	0	6	6
5	11	0	0	83	94
6	0	0	0	0	0
7	6	0	0	17	23
Mean	40	0	0	20	61
May 11, 1983					
1	-	-	-	-	-
2	145	0	22	51	218
3	44	0	11	28	83
4	28	0	0	39	67
5	22	0	0	61	83
6	17	0	17	83	117
7	0	0	0	17	17
Mean	43	0	8	47	98
May 22, 1983					
1	-	-	-	-	-
2	1089	0	17528	11	18628
3	-	-	-	-	-
4	28	0	61	17	106
5	-	-	-	-	-
6	0	0	17	17	34
7	-	-	-	-	-
Mean	372	0	5868	15	6256

Transect	Harpac-ticoid Copepod	Calanoid Copepod	Copepod Nauplii	Others	Total
May 26, 1983					
1	-	-	-	-	-
2	-	-	-	-	-
3	350	0	50	39	439
4	100	0	0	105	205
5	44	0	0	89	133
6	50	0	0	33	83
7	67	0	0	34	101
Mean	122	0	10	60	192
June 1, 1983					
1	-	-	-	-	-
2	7000	0	21944	22	28966
3	678	0	217	239	1134
4	106	0	17	134	257
5	17	0	28	28	73
6	0	0	0	50	50
7	167	0	133	84	384
Mean	1328	0	3723	93	5144
June5,1983					
1	-	-	-	-	-
2	3438	0	13855	0	17293
3	167	0	50	71	288
4	103	0	25	126	254
5	8	0	0	59	67
6	0	0	0	0	0
7	-	-	-	-	-
Mean	743	0	2786	51	3580
June 8, 1983					
1	-	-	-	-	-
2	9167	0	68542	0	77709
3	13542	0	35000	0	48542
4	351	0	700	89	1140
5	17	0	59	51	127
6	13	0	13	25	51
7	50	0	13	13	76
Mean	3857	0	17388	30	21274

Transect	Harpacticoid Copepod	Calanoid Copepod	Copepod Nauplii	Others	Total
June 12, 1983					
1	-	-	-	-	-
2	2917	0	5521	104	8542
3	6067	0	27396	2500	35963
4	1676	0	3763	38	5477
5	125	0	84	46	255
6	0	0	38	13	51
7	-	-	-	0	0
Mean	2157	0	7360	540	10057
June 15, 1983					
1	-	-	-	-	-
2	2917	0	23056	0	25973
3	9896	0	60104	0	70000
4	1855	0	2909	17	4781
5	238	0	63	139	440
6	26	0	13	26	65
7	25	0	50	50	125
Mean	2493	0	14366	39	16897
June19, 1983					
1	-	-	-	-	-
2	8438	0	10000	313	18751
3	2492	0	713	47	3252
4	363	0	92	55	510
5	21	0	38	25	84
6	50	0	25	26	101
7	-	-	-	-	-
Mean	2273	0	2174	93	4540
June 23, 1983					
1	938	782	14844	157	16721
2	3751	0	21563	313	25627
3	1980	104	2292	0	4376
4	275	0	63	64	402
5	63	0	59	38	160
6	13	0	88	13	114
7	501	0	88	126	715
Mean	1074	127	5571	102	6874

Transect	Harpacticoid Copepod	Calanoid Copepod	Copepod Nauplii	Others	Total
		June 26, 1983			
1	938	1406	15938	157	18439
2	1771	0	13021	417	15209
3	2917	0	4896	208	8021
4	1953	0	1771	0	3724
5	46	0	42	33	121
6	0	0	100	13	113
7	13	0	50	13	76
Mean	1091	201	5117	120	6529
		June 29, 1983			
1	1094	3907	14219	313	19533
2	3126	104	10313	730	14273
3	3647	0	2500	104	6251
4	2188	209	729	104	3230
5	-	-	-	-	-
6	-	-	-	-	-
7	-	-	-	-	-
Mean	2514	1055	6940	313	10821
		July 3, 1983			
1	2792	0	4560	1293	8645
2	3134	0	489	6	3629
3	494	0	33	45	572
4	133	0	55	39	227
5	89	0	56	62	207
6	17	0	0	0	17
7	50	0	0	17	67
Mean	958	0	742	209	1909

APPENDIX C

TRANSECT MEAN DENSITIES OF ZOOPLANKTON (NUMBERS/M^3) IN THE SOUTH FORK COOS RIVER, 1984

Transect	Harpacticoid Copepod	Calanoid Copepod	Copepod Nauplii	Others	Total
		May 13, 1984			
1	-	-	-	-	-
2	209	0	11042	0	11251
3	313	0	0	0	313
4	0	0	0	0	0
5	-	-	-	-	0
6	-	-	-	-	0
Mean	174	0	3681	0	2313
		May 20, 1984			
1	-	-	-	-	-
2	208	0	0	0	208
3	0	0	0	0	0
4	0	0	0	0	0
5	0	0	0	0	0
6	-	-	-	-	-
Mean	52	0	0	0	52
		May 30, 1984			
1	-	-	-	-	-
2	0	0	625	0	625
3	0	0	0	0	0
4	0	0	0	0	0
5	0	0	0	0	0
6	0	0	0		0
Mean	0	0	125	0	125

Transect	Harpac-ticoid Copepod	Calanoid Copeopod	Copepod Nauplii	Others	Total
		June 9, 1984			
1	-	-	-	-	-
2	225	0	0	0	225
3	17	0	0	0	17
4	8	0	0	8	16
5	25	58	0	0	83
6	17	683	0	8	708
Mean	58	148	0	3	209
		June 16, 1984			
1	0	0	0	0	0
2	0	0	0	0	0
3	0	0	0	0	0
4	0	0	0	0	0
5	0	0	0	0	0
6	0	0	0	0	0
Mean	0	0	0	0	0
		June 28, 1984			
1	2917	3333	15000	0	21250
2	5000	0	10000	0	15000
3	4375	0	28542	0	32917
4	1592	42	6375	0	8009
5	67	92	83	0	242
6	-	-	-	-	-
Mean	2790	693	12000	0	15484

APPENDIX D

TRANSECT MEAN DENSITIES OF ICHTHYOPLANKTON (NUMBERS/M^3) IN THE SOUTH FORK COOS RIVER, 1983.

Transect	Striped Bass		American Shad		Bay Goby		Prickly Sculpin
	Eggs	Larv	Eggs	Larv	Eggs	Larv	Larv
May 4, 1983							
1	-	-	-	-	-	-	-
2	0	0	0	0	0	0	220
3	0	0	31	0	0	0	157
4	0	0	13	0	0	0	283
5	0	0	6	0	0	0	352
6	0	0	0	0	0	0	38
7	0	0	0	0	0	0	38
Mean	0	0	8	0	0	0	181
May 11, 1983							
1	-	-	-	-	-	-	-
2	0	0	0	0	0	0	57
3	0	0	0	0	0	0	409
4	0	0	0	0	0	0	189
5	0	0	0	0	0	0	107
6	0	0	0	0	0	0	0
7	0	0	0	0	0	0	19
Mean	0	0	0	0	0	0	130
May 22, 1983							
1	-	-	-	-	-	-	-
2	113	0	0	0	0	0	195
3	-	-	-	-	-	-	-
4	170	0	0	0	0	0	50
5	-	-	-	-	-	-	-
6	0	0	0	0	0	0	0
7	-	-	-	-	-	-	-
Mean	94	0	0	0	0	0	82

Transect	Striped Bass		American Shad		Bay Goby		Prickly Sculpin
	Eggs	Larv	Eggs	Larv	Eggs	Larv	Larv
			May 26, 1983				
1	-	-	-	-	-	-	-
2	-	-	-	-	-	-	-
3	0	0	83	23	0	0	143
4	0	0	30	8	0	0	136
5	0	0	0	0	0	0	8
6	0	0	0	0	0	0	0
7	0	0	151	0	0	0	0
Mean	0	0	53	6	0	0	57
			June 1, 1983				
1	-	-	-	-	-	-	-
2	0	0	100	0	0	5	82
3	0	0	116	33	0	0	0
4	0	0	42	0	0	0	7
5	0	0	10	10	0	0	10
6	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0
Mean	0	0	45	7	0	1	17
			June 5, 1983				
1	-	-	-	-	-	-	-
2	41	0	46	14	0	0	11
3	488	4**	34	13	0	0	6
4	100	0	42	40	0	0	0
5	75	0	30	30	0	0	0
6	0	0	0	0	0	0	0
7	-	-	-	-	-	-	-
Mean	141	1	30	19	0	0	3
			June 8, 1983				
1	-	-	-	-	-	-	-
2	165	8*	121	12	0	274	33
3	3	0	51	6	0	0	4
4	5	6*	27	21	0	0	6
5	0	0	9	25	0	0	9
6	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0
Mean	29	2	35	11	0	46	9

Transect	Striped Bass		American Shad		Bay Goby		Prickly Sculpin
	Eggs	Larv	Eggs	Larv	Eggs	Larv	Larv
			June 12, 1983				
1	–	–	–	–	–	–	–
2	0	0	16	6	0	855	0
3	0	4**	32	20	0	60	4
4	0	0	7	52	0	0	0
5	0	0	8	139	0	0	0
6	0	0	27	27	0	0	0
7	–	–	–	–	–	–	–
Mean	0	1	18	49	0	183	1
			June 15, 1983				
1	–	–	–	–	–	–	–
2	66	27*	9	30	0	784	9
3	79	13*	0	0	0	5	18
4	7	4*	22	56	0	0	0
5	0	0	28	0	0	0	0
6	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0
Mean	25	7	10	14	0	132	5
			June 19, 1983				
1	0	0	0	0	15	620	0
2	22	0	79	13	0	48	13
3	4	5*	128	29	0	0	18
4	0	7*	31	10	0	0	6
5	0	4*	0	9	0	0	12
6	0	0	0	11	0	0	0
7	–	–	–	–	–	–	–
Mean	4	3	40	12	3	111	8
			June 23, 1983				
1	0	0	0	0	3330	348	0
2	0	0	0	0	0	200	0
3	0	4**	127	28	0	0	0
4	0	0	16	18	0	0	0
5	0	0	34	0	0	0	0
6	0	0	8	0	0	0	0
7	0	0	0	0	0	0	0
Mean	0	1	26	6	476	78	0

Transect	Striped Bass		American Shad		Bay Goby		Prickly Sculpin
	Eggs	Larv	Eggs	Larv	Eggs	Larv	Larv
			June 26,1983				
1	0	0	0	0	409	1162	0
2	0	0	0	0	0	876	0
3	9	0	33	0	0	16	0
4	0	0	16	45	0	0	0
5	0	0	34	9	0	0	0
6	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0
Mean	1	0	12	8	58	293	0
			June 29, 1983				
1	0	0	0	0	228	938	0
2	0	0	0	0	0	757	0
3	0	7*, 4**	0	10	0	3	0
4	12	0	3	6	0	0	0
5	0	0	0	5	0	0	0
6	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0
Mean	2	2	0	3	33	243	0
			July 3, 1983				
1	0	0	0	7	0	20	0
2	0	0	13	23	0	0	0
3	0	0	31	29	0	0	0
4	0	0	47	9	0	0	0
5	0	0	22	0	0	0	0
6	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0
Mean	0	0	16	10	0	3	0
			July 11, 1983				
1	0	0	0	0	669	591	0
2	0	0	0	0	10	515	0
3	0	0	7	7	0	0	0
4	0	0	7	13	0	0	0
5	0	0	9	5	0	0	0
6	-	-	-	-	-	-	-
7	-	-	-	-	-	-	-
Mean	0	0	5	5	136	221	0

* Yolk-Sac Larvae

** Post Yolk-Sac Larvae

APPENDIX E

TRANSECT MEAN DENSITIES OF ICHTHYOPLANKTON (NUMBERS/M^3) IN THE SOUTH FORK COOS RIVER, 1984.

Transect	Striped Bass		American Shad		Bay Goby		Prickly Sculpin
	Eggs	Larv	Eggs	Larv	Eggs	Larv	Larv
May 13,1984							
1	–	–	–	–	–	–	–
2	0	0	19	8	0	0	481
3	0	0	30	0	0	0	245
4	0	0	0	0	0	0	805
5	0	0	0	0	0	0	418
6	–	–	–	–	–	–	–
Mean	0	0	12	2	0	0	487
May 20,1984							
1	–	–	–	–	–	–	–
2	35	0	7	0	0	0	142
3	485	0	0	0	0	0	75
4	0	0	0	0	0	0	74
5	0	0	10	0	0	0	55
6	–	–	–	–	–	–	–
Mean	130	0	4	0	0	0	87
May 27,1984							
1	–	–	–	–	–	–	–
2	34	0	17	0	0	0	46
3	213	0	0	20	0	0	43
4	0	0	0	0	0	0	25
5	19	0	0	0	0	0	56
6	–	–	–	–	–	–	–
Mean	67	0	4	5	0	0	43
May 30,1984							
1	–	–	–	–	–	–	–
2	712	38*	109	18	0	0	75
3	1970	22*	98	0	0	0	33
4	453	0	8	116	0	0	116
5	120	0	0	10	0	0	95
6	0	0	0	0	0	0	0
Mean	651	12	43	29	0	0	64

Transect	Striped Bass		American Shad		Bay Goby		Prickly Sculpin
	Eggs	Larv	Eggs	Larv	Eggs	Larv	Larv
June 1, 1984							
1	-	-	-	-	-	-	-
2	0	9*	20	0	0	0	361
3	21	21*	0	42	0	0	155
4	14	14*	14	50	0	0	124
5	0	0	25	13	0	0	0
6	0	0	0	0	0	0	0
Mean	7	9	12	21	0	0	128
June 3, 1984							
1	50	0	50	22	0	0	193
2	175	0	161	8	0	0	17
3	0	0	405	0	0	0	0
4	0	0	80	0	0	0	10
5	0	0	49	10	0	0	0
6	0	0	18	35	0	0	18
Mean	38	0	127	13	0	0	40
June 5, 1984							
1	0	0	304	30	0	0	10
2	0	0	452	67	0	0	13
3	0	0	26	0	0	0	0
4	0	10**	0	42	0	0	30
5	0	0	25	0	0	0	12
6	0	0	40	0	0	0	0
Mean	0	2	141	23	0	0	11
June 9, 1984							
1	-	-	-	-	-	-	-
2	0	0	0	0	0	0	11
3	0	0	0	0	0	0	10
4	0	0	0	0	0	0	10
5	0	0	12	0	0	0	0
6	0	0	0	0	0	0	0
Mean	0	0	2	0	0	0	6

Transect	Striped Bass		American Shad		Bay Goby		Prickly Sculpin
	Eggs	Larv	Eggs	Larv	Eggs	Larv	Larv
			June 16, 1984				
1	1681	0	0	19	0	0	0
2	6549	0	0	0	0	0	0
3	2184	0	0	10	0	0	10
4	338	0	110	0	0	0	0
5	305	0	165	10	0	0	0
6	43	0	21	0	0	0	0
Mean	1850	0	49	7	0	0	1
			June 19, 1984				
1	0	0	0	0	0	521	0
2	0	0	15	30	0	39	0
3	0	0	0	18	0	0	0
4	0	0	14	22	0	0	0
5	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0
Mean	0	0	5	12	0	93	0
			June 28, 1984				
1	0	0	0	0	980	478	0
2	0	0	0	0	797	114	0
3	0	0	0	0	0	26	10
4	0	0	9	44	0	0	0
5	0	0	9	32	0	0	0
6	-	-	-	-	-	-	-
Mean	0	0	0	15	355	124	0

* Yolk-Sac Larvae
** Post Yolk-Sac Larvae

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